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THE CELL DOCTRINE

DR TYSON.

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Production of formed material from germinal matter in Epithelial cells, from section through layer of Epithelium covering papillæ of the tongue. ×700.

FORMATION OF PUS.

To illustrate the change in germinal matter of an Epithelial cell, resulting from increased nutrition, showing the manner in which the germinal matter of a normal cell, if supplied freely with pabulum, may give rise to pus.

Young. Fully formed. TENDON.

Young. Fully formed. CARTILAGE.

MUSCLE.

ELASTIC TISSUE.

The arrow shows the direction in which germinal matter is supposed to be moving.

NERVE.

Development of young, dark-bordered nerve fibres, at an early period, showing germinal matter and formed material of elementary parts. ×1500.

AMŒBA.

Pure germinal matter. ×3000.

New centre or nucleolus.
Oldest part of formed material.
Youngest part of formed material.
Germinal matter (nucleus).
Course of pabulum.

PLATE ILLUSTRATING DR. BEALE'S VIEWS.

H. Sidwell, Sc.

THE CELL DOCTRINE:

ITS HISTORY AND PRESENT STATE.

FOR THE USE OF

STUDENTS IN MEDICINE AND DENTISTRY.

ALSO,

A COPIOUS BIBLIOGRAPHY OF THE SUBJECT.

BY

JAMES TYSON, M.D.,

LECTURER ON MICROSCOPY IN THE UNIVERSITY OF PENNSYLVANIA, AND ON PHYSIOLOGY IN THE PENNSYLVANIA COLLEGE OF DENTAL SURGERY; FELLOW OF THE COLLEGE OF PHYSICIANS OF PHILADELPHIA, ETC. ETC.

WITH

A COLORED PLATE AND OTHER ILLUSTRATIONS.

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THIS LITTLE VOLUME

IS RESPECTFULLY INSCRIBED,

BY

THE AUTHOR.

PREFACE.

THE author has become convinced, by several years' intimate intercourse with students of medicine, that their acquaintance with the subjects he has endeavored to include in this little volume would be facilitated, if the views, which are now taught and scattered throughout the often expensive works of their authors, were collected in a convenient form for study and reference. Taking it for granted that a knowledge of this subject is of fundamental importance in its bearing upon the study of physiology and pathology, and stimulated by the frequent inquiries of students for an appropriate source of information, he has prepared what he now submits to them.

He has sought to obtain a continuous history of the evolution of the "cell doctrine" up to its present state, without embarrassing his pages with a large number of isolated facts. He has attempted, how-

ever, to secure a completeness, and to make the work useful to physicians and others engaged in research, by careful references, and the addition of a bibliography, which he has sought to make accurate and extended. Some authors may have been overlooked; such the writer cordially invites to send him references to their own papers, or to those of others they believe to have a bearing upon the subject.

332, South Fifteenth Street.
February, 1870.

ILLUSTRATIONS.

PLATE.—ILLUSTRATING DR. BEALE'S VIEWS.

Figs. 1 to 7. Production of formed material from germinal matter in epithelial cells, from section through layer of epithelium covering papillæ of frog's tongue.

Figs. 7 to 11. Formation of Pus.

Fig. 11. " " Tendon.

Fig. 12. " " Cartilage.

Fig. 13. " " Muscle.

Fig. 14. " " Elastic Tissue.

Fig. 15. " " Nerve.

Fig. 16. Amœba.

Fig. 17. Illustrating Nutrition of Cell.

INTERCALATED.

Fig. 1. Illustrating Globular Theory. After Virchow.

Fig. 2. Cellular Tissue from the Embryo Sac of Chamædorea Schiedeana in the act of formation. After Schleiden.

Fig. 3. From the Point of a Branchial Cartilage of Rana Esculenta. After Schwann.

Figs. 4 to 12. Formation of Nuclei and Cells from Molecules, according to Bennett.

Fig. 12. Diagram of the Investment Theory. From Virchow.

Fig. 13. Formation of Pus from subcutaneous connective tissue. From Virchow.

Fig. 14. Formation of Pus from interstitial connective tissue of muscle. From Virchow.

Fig. 15. Development of Cancer from connective tissue. From Virchow.

Fig. 16. Connective Tissue Corpuscles anastomosing one with the other. From Virchow.

Fig. 17. Formation of Elastic Tissue, according to Virchow.

THE CELL DOCTRINE.

THE idea that animals and plants, however complex their organization, are really composed of a limited variety of elementary parts, constantly recurring, was appreciated by Aristotle, while it appears to have been even more clearly conceived by the acknowledged father of medical science, Galen. Fallopius of Modena, 1523–1562, to whom we are indebted for our knowledge of the conceptions of Galen in regard to these "partes similares" or "simplices," has further developed the subject of general anatomy in his "Lectiones de Partibus Similaribus Humani Corporis." But these "partes similares" of Fallopius, which were bone, cartilage, fat, flesh, nerve, ligament, tendon, membrane, vein, artery, nails, hairs, and skin, plainly do not correspond with the "elementary parts" or "cells" of the present day. They were ultimate to Fallopius, as stated by Prof. Huxley, because he could go no further, "though it is, of course, a very different matter whether we are stopped by the imperfection of our instruments of analysis, as these older observers were, or by having really arrived at parts no longer analyzable."* These "partes similares"

* The Cell Theory—a Review, by T. H. Huxley: Br. & Foreign Med.-Chir. Rev. for Oct., 1853, No. xxiv.

really correspond to the "tissues" of the present day, which are *collections of elementary parts.* The conceptions of these older writers with regard to the "vital endowment" or "independent vitality" of their similar parts or tissues, were singularly correct, and correspond almost identically with those held by the majority of physiologists of the present day.

Further than this, however, the anatomists of the period of Fallopius could not go—not because, as we now well know, they had arrived at parts no longer analyzable, but because of their imperfect means of analysis.

It is probable that the magnifying properties of lenses were known to the Egyptians, as well as the Greeks and Romans, over 2000 years ago; since a table of refractive powers is introduced into his "Optics" by Ptolemy, since Aristophanes, the comic Athenian poet (B.C. 500), speaks of "burning spheres" of glass as sold in the grocers' shops of Athens, and since both Pliny and Seneca refer to lenses and their magnifying properties; while lenses themselves have been found in the ruins of Nineveh, Herculaneum, and Pompeii. But it is quite certain, also, that they did not become available as compound microscopes until about 1590, when the Jansens, father and son, of Holland, are said to have invented the compound microscope. Fontana, in 1646, writes that he had invented the microscope in 1618. Galileo, as early as 1612, is said to have sent a microscope to King Sigismund of Poland, though whether it was his own invention, or made after the pattern of another, is more difficult to determine. In 1685

Stelluti published a description of the parts of a bee he had examined with the microscope, and although George Hufnagle is said to have published in Frankfort, in 1592, a work upon insects, illustrated by fifty copper plates, it is highly probable that these, as well as very many most important observations made after the invention of the compound microscope, were made with the simple instrument.*

It is impossible to estimate the assistance the microscope has been to us in opening up the minute structure of animals and vegetables, and in thus affording a reliable basis on which to build a doctrine of organization. Prof. Huxley says, "The influence of this mighty instrument of research upon biology, can only be compared to that of the galvanic battery, in the hands of Davy, upon chemistry. It has enabled *proximate* analysis to be *ultimate*."† But it is more than this. Since, as he correctly states, it has enabled *proximate* physical analysis to become ultimate, it corresponds, not to the galvanic battery alone, but to all the appliances made use of in ultimate chemical analysis.

The time prior to the invention of the compound microscope may be considered as the *first period* in *histology;* that between this date and that of the observations of Schleiden and Schwann (1838), inclusive, the *second period;* while the time subsequent to

* For an interesting and exhaustive history of the invention of the compound microscope, see Das Mikroskop, Theorie, Gebrauch, Geschichte und gegenwärtiger Zustand desselben. Von P. Harting. In drei Bänden. Braunschweig: 1866. Dritter Band, ss. 11–35.

† Huxley, loc. citat., p. 290.

*

these observations becomes appropriately the *third period.* Notwithstanding the imperfect state of instruments during quite two hundred years from this date, a flood of facts was added to our knowledge of the minute structure of living things.

Borellus, of Pisa, seems first to have used the microscope in the examination of the higher animal structures, about the year 1656, but his observations were grossly misinterpreted in his attempt to adapt them to the prevailing idea of the day, that diseases were caused by animalculæ in the blood and tissues. As a result, he describes pus corpuscles as animalcules, and even says he has seen them delivering their eggs.

According to Boerhaave, Swammerdam had recognized the blood corpuscle in 1658.

Malpighi,* between 1661 and 1665, had witnessed the circulation of the blood, and had published observations upon the minute structure of the lungs, which he had even compared to a racemose gland,† kidneys, spleen, liver, and membranes of the brain, and with some of these structures his name has become inseparably associated. In 1667, Robert Hooke‡ pointed out the *cellular* structure of plants, and Malpighi§ further elaborated the same subject with considerable accuracy in his "Anatome Planta-

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* Malpighi, Opera Omnia. Lond.: 1686.

† Fort, Anatomie et Physiologie du Poumon, considere comme organe de Secretion. Paris: 1867, Preface: or a notice of Dr. Fort's book, by the writer, in American Journal of Medical Sciences, October, 1869.

‡ Hooke, Rob., Micrographia. Lond.: 1667.

§ Malpighi, Anatome Plantarum. London: 1670.

rum," in 1670. He showed that the walls of the "cells," or "vesicles," were separable, that they could be isolated; and gave to each the name "*utriculus*," believing also the "cell," or "utriculus," to be an independent entity. The latter observer* also recognized the blood corpuscle. Leeuwenhoek, in 1687,† described these corpuscles with considerable accuracy, not only in man, but also in the lower animals. He also demonstrated the capillaries, examined most of the tissues, and made the discovery of the spermatozoids, which he conceived to be spermatozoa or sperm animals, and of different sexes.

No attempt, however, seems to have been intelligently made at building up the tissues by an ultimate physical element, to correspond with the "atom" of the inorganic chemist, prior to that of Haller. He resolved the solid parts of animals and vegetables into the "*fibre*" (*fibra*), and an "*organized concrete.*" To the former he assigns the most important position, asserting that it is to the physiologist what the line is to the geometrician; that a "fibre," in general, may be considered as resembling a line made up of points, having a moderate breadth, or rather as a slender cylinder.‡

The second elementary substance of the human body according to Haller, the "organized concrete," must not be lost sight of, as appears to have been

* Malpighi, Opera Posthuma. London: 1697.

† Leeuwenhoek, Opera Omnia seu Arcana Naturæ detecta. Tom. ii, p. 421. Leyden: 1687. Vel Opera Omnia, &c., Lugd. Batav.: 1722.

‡ Haller, Elementa Physiologiæ, vol. i, lib. i, sect. i. Lausan. Helvet.: 1757.

the case with many eminent authorities who have attempted to give his views. This, he says, is a mere glue, evasated and concreted, not within the fibres, but in the spaces betwixt them, in illustration of which it is stated, that cartilages seem to be scarcely anything else besides this glue concreted. But these views of Haller were clearly not based upon microscopic observation, though the microscope had been for some time in use. For Haller himself tells us that the fibre is invisible, and to be distinguished only by the "mind's eye,"—*invisibilis est ea fibra, solâ mentis acie distinguimus.** No allusion to the cell beyond the imperfect description of the blood corpuscles and spermatozoids appears to have been made by Haller.

Better founded, in being based upon observation, was the theory of Wolf, and it contained many of the elements of truth. For an available exposition of these views, physiologists are much indebted to Prof. Huxley, who in the able review alréady cited, has presented them as agreeing partially, also, with

* A singular discrepancy exists between these words of Haller and those found in both the Latin and English editions of the "elegant compend" of Haller's works printed in Edinburgh, the former in 1766, and the latter (an edition in the possession of the writer), in 1779, under the inspection of William Cullen, M.D. In the latter, we have the following: "The solid parts of animals and vegetables have this fabric in common, that their elements, or the smallest parts we can see *by the finest microscope*, are either fibres or an organized concrete."[1]

[1] First Lines of Physiology. By the celebrated Baron Albertus Haller, M.D. Translated from the correct Latin edition, and printed under the inspection of William Cullen, M.D. Edinburgh: 1779.

his own. The doctrine of Wolf, as given by Prof. Huxley, is as follows: "Every organ is composed, at first, of a mass of clear viscous, nutritive fluid, which possesses no organization of any kind, but is at most composed of globules. In this semi-fluid mass, cavities (Blaschen, Zellen) are now developed; these, if they remain rounded or polygonal, become the subsequent cells, if they elongate, the vessels; and the processs is identically the same, whether it is examined in the vegetating point of a plant, or in the young budding organs of an animal. Both cells and plants may subsequently be thickened by deposits from the 'solidescible' nutritive fluid. In the plant, the cells at first communicate, but subsequently become separated from one another; in the animal, they always remain in communication. In *each case they are mere cavities and not independent entities; organization is not affected by them, but they are the visible results of the action of the organizing power inherent in the living mass*, or what Wolf calls the *vis essentialis*. For him, however, this *vis essentialis* is no *Archaeus*, but simply a convenient name for two facts which he takes a great deal of trouble to demonstrate: the first, the existence in living tissues (before any passages are developed in them), of currents of the nutritious fluid determined to particular parts, by some power which is independent of all external influence; and the second, the peculiar changes of form and composition, which take place in the same manner."*

* Huxley, loc. citat., p. 293–4. Wolf, C. F., Theoria Generationis, 1759. Ed. Nova, 1774.

Two points are here particularly to be observed as cardinal,—first, the non-independence of cells, either anatomically or physiologically; that they are effects, *passive results*, and *not causes* of a vitalizing or organizing force; second, that organization takes place from the "differentiation" of the homogeneous living mass in these parts, through the agency of the vis essentialis or inherent vital force. The radical difference between these principles of development and those generally held at the present day, will be better appreciated when these latter have been worked out. An acknowledged error may also be pointed out,—the probable result of the inferiority of the instruments of that day—that of supposing the cells of plants to communicate when in their youngest state.

This theory, however, full as it was of original conception, and based on actual observation, seemed to claim little attention, and would have been still less known but for the labors of Prof. Huxley. The "fibre" theory of Haller was still further expanded, and that fibres were the groundwork of nearly all the tissues, continued the prevailing view, until the latter part of the eighteenth century, and there are few of the older physiologies even of a later date, which do not contain an account of it. Naturally, it maintained itself longest in the case of the fibrous tissues, since the appearances of these tissues, when examined by the highest powers, are those of structures apparently composed of fibres.

The reaction which took place at the date referred to against the "fibre" theory, culminated in the

"globular" theory, due less to speculation than erroneous methods of observation and imperfect instruments. Leeuwenhoek* (1687) early announced the "globular" structure of the primitive tissues of the body, but the "globule" apparently attracted little notice until this period of reaction against the "fibre," when it claimed the attention of Prochaska† (1779), Fontana‡ (1787), the brothers Wenzel§ (1812), Treviranus‖ (1816), Bauer¶ (1818 and 1823), Heusinger** (1822), MM. Prevost and Dumas,†† Milne-Edwards‡‡ (1823), Hodgkin§§ (1829), Baumgärt-

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* Leeuwenhoek, op. citat.

† Prochaska, De Structura Nervorum. Vind.: 1779. Opera min., Pars i.

‡ Fontana, Sur les Poisons, 1787, ii, 18; Abhandlung über das Viperngift, das Amerikanische Gift, u. s. w. Aus dem Italien. Berlin: 1787.

§ Wenzel, Joseph and Charles. De structura cerebri. Tubing.: 1812.

‖ Treviranus, Vermischte Schriften, Anatom. und Physiolog. Inhalts. Bd. i. Gottingen: 1816.

¶ Bauer, Philosoph. Transac. for 1818, and Sir E. Home's Lectures on Comparative Anatomy. Vol. iii, Lect. iii. London: 1823.

** Heusinger, System der Histologie. Thl. i, Eisenach: 1822–4.

†† MM. Prevost and Dumas, Bibliothèque Universelle des Sciences et Arts, T. xvii.

‡‡ Milne-Edwards, Mémoire sur la Structure Elémentaire des Principaux Tissues Organiques des Animaux. Paris: 1823. Also, Recherches Microscopiques sur la Structure Intime des Tissues Organiques des Animaux, in Ann. des Sci. Nat., Dec., 1826.

§§ Hodgkin, in Grainger's Elements of General Anatomy. London: 1829. Also, Hodgkin and Fisher's translation of M. Edwards "Sur les Agens Physiques." London: 1832. Hodgkin's Lectures on the Morbid Anatomy of the Serous and Mucous Membranes. London: 1836, p. 26. Am. Ed. Philada.: 1838, vol. i, pp. 17–18.

ner* (1830), F. Arnold† (1836), Dutrochet‡ (1837), Raspail§ (1839); all except Hodgkin admitting in greater or less degree the importance of the globule as an ultimate physical element; while it is evident, also, that there was much confusion in the use of terms,—the words *globule*, *granule*, and *molecule*,‖ being often indiscriminately used, and the word *globule* sometimes used to indicate what is now clearly recognized as the "cell."

Prochaska,¶ in 1779, described the brain as made up of globules eight times smaller than blood glob-

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* Baumgärtner, R. H., Lehrbuch der Physiologie mit Nutzanwendung auf die ärztliche Praxis. 1853.

† Arnold, F., Lehrbuch der Physiologie des Menschen. Erst. Theil, Zurich: 1836.

‡ Dutrochet, Mémoires pour servir a l'Histoire Anatomique et Physiologique des Végétaux et des Animaux. T. i, ii, Atlas. Paris: 1837.

§ Raspail, Système de Chimie Organique. 2e ed., T. i, ii. Brus.: 1839. Avec Atlas.

‖ The German authors of this period and even more recent times (Henle, 1841, Virchow, 1858), at least in speaking of the development of histology, seem to use indiscriminately the terms *granule* or *molecule*, and *globule*, whereas they are morphologically something distinct. A *globule* is usually held to be a body, which, under the microscope, is more or less spherical in form, possessing a *bright* centre, and *dark* outline,—the width of this outline being directly as the difference between the refracting power of the globule itself and that of the menstruum in which it floats. Thus, the dark outline of a globule of oil floating in water is wider than that of the same globule floating in glycerine. A *granule* or *molecule*, on the other hand, is *indeterminate* in size and shape, and appears as a mere dot under the highest powers of the microscope. It is true that what appears as a granule under a low power, may appear as a globule under a higher.

¶ Prochaska, Opera Minora, Part I, p. 342.

ules. In the year 1801, the philosophic mind of Bichat elaborated his excellent classification, but he seems to have made no original investigations in minute structure, or to have adopted any special theory of an ultimate physical element. The brothers Joseph and Charles Wenzel,* in 1812, described the brain as composed of globules of small size. Among the earliest histologists worthy of mention, is Treviranus,† whose elements, according to Henle, were first, a homogeneous, formless matter; second, fibres; third, globules (kügelchen). Mr. Bauer,‡ quoted as a most experienced microscopic observer by Sir Everard Home, in 1818, and again in 1823, described the ultimate globules of the brain and of muscular fibre as of the size of a globule of blood when deprived of its coloring matter, or about $\frac{1}{2000}$ of an inch in diameter. The fibre was excluded as an ultimate element of organization by Heusinger§ in 1822–4, who started all tissues from the *globule*, still, however, retaining the formless material of Haller and Treviranus. Heusinger formed the fibre by the linear apposition of his globular elementary parts, and even explained how canals and vessels were formed by a similar arrangement of *vesicles* which had originated from the globules. The account given by Henle‖ of the method in which Heusinger built up his fibres and vessels is interesting, and is worth translating, since

* Wenzel, op. citat., p. 24.
† Treviranus, op. citat.
‡ Bauer, op. citat.
§ Heusinger, op. citat., p. 112.
‖ Henle, Allgemeine Anatomie. Leipzig: 1841, p. 128.

there is in these views an approximation to the truth. "As the result of an equal contest between contraction and expansion, there arises the *globule*, of which all organisms, all organic parts, are originally composed. By a stronger exercise (Spannung, tension) of power, there originates from the often mere homogeneous globule, the *vesicle*. Where in an organism *globules* and a *formless mass* are present, the *globules* arrange themselves according to chemical(?) laws and form *fibres*. Where vesicles arrange themselves, there arise *canals* and *vessels*." In the latter sentence one cannot fail to note a close approximation to the truth, though the facts upon which the theory was based are partly false and partly misinterpreted.

But the observations and writings of Milne Edwards* may be looked upon as having given, more than any other author, position and popularity to the "globular theory." He examined all the principal tissues, and announced that the fibres of the then so-called cellular (fibrous) tissues, membranes composed of these fibres, muscle and nerve, were composed of globules of about the same size, from $\frac{1}{8000}$ to $\frac{1}{7500}$ of an inch in diameter; whence he concluded that these spherical corpuscles, by their aggregation, constituted all organic textures, vegetable or animal, and whatsoever their properties or functions. There is little doubt but that many of these so-called globules described by Edwards were really cells, seen with indifferent instruments, and further distorted by the glare of direct sunlight.

* Edwards, loc. citat.

Similar, as regards the element of organization, were the views of Baumgartner* and Arnold,† who built up the cell wall by the apposition of globules (to which the term granules would now perhaps be applied‡), so as to constitute a membrane within which other globules (granules) remained to constitute contents.

Fig. 1.

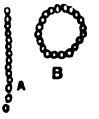

Fig. 1. Illustrating the globular theory.

A, Fibre, composed of elementary granules (molecular granules), drawn up in a line. B, Cell, with spherically arranged granules. (After Virchow, slightly modified.)

The error of Edwards seems to have been clearly pointed out by Dr. Hodgkin,§ though much importance was still attached to the globule as an element of organization (but perhaps from this time forward, more in the stricter sense of the term granule), which has continued, in this latter sense, to the present day.

From the foregoing facts, it is evident that for some time prior to the year 1838, the cell had come to be quite universally recognized as a constantly recurring element in vegetable and animal tissues; though as yet little importance had been attached to it as an element of organization, nor had its characters been

* Baumgartner, loc. citat ; also, Virchow, Cellular Pathology, Am. Ed. of Chance's Translation. Philada.: 1863, p. 53.

† Arnold, loc. citat.; also, Virchow, Cellular Pathology, Am. Ed. of Chance's Translation. Philada.: 1863, p. 53.

‡ See note to p. 22. § Hodgkin, loc. citat.

clearly determined. As stages in its growing importance may be mentioned, the demonstration of the cellular structure of plants by Robert Hooke in 1667, the further elaboration of this subject by Malpighi, and his statement that each "utriculus" was an independent entity, the description of Heusinger, in 1822, of the mode of formation of vessels by the apposition of *vesicles*, already referred to, and the announcement, though erroneous, of Döllinger, in 1828, that the body is built up of blood corpuscles which move in wall-less (wandlos) channels in the tissues.

A most important contribution to the anatomy of the cell was now made, in the discovery of the "nucleus," by Dr. Robert Brown, of Edinburgh; whose paper, "Organs and Mode of Fecundation in Orchideæ and Asclepiadeæ," appeared in the Transactions of the Linnean Society of London, in 1833. He failed, however, to appreciate its importance, though its discovery was another fact added to those necessary to complete the data on which has been founded the so-called "cell theory."

Singularly near the truth did Raspail* approach, in 1837, when he tells us that in the condition of development there are *vesicles* or *cells*, endowed with life and the property, almost unlimited, of producing out of themselves other cells of the same structure and similar endowments, of spherical form, and capable of taking up oxygen when exposed to the atmosphere; that the cell membrane in its fresh state is structureless. Yet he considers the organic

* Raspail, op. citat.

cell as made up of granules or atoms, spirally arranged about an ideal axis, comparing the cell with the crystal rather than the ultimate element or atom of which the crystal is made up, and speaks of organization as crystallization in vesicles (*crystallization vesiculaire*).

Similar was the view of Dutrochet,* who divided the component parts of the body into *solids* and *fluid*. The *solids* were formed by the aggregation of cells of a certain degree of firmness; the *liquids*, as the blood, are also made up of cells, which, however, float freely among each other, and there are also tissues in which the cells are so feebly united, that one can scarcely tell in what class to place them. The contents of the cell may be more or less solid, but the highest degree of vitality is only compatible with liquid cell contents. *Muscular fibres, and the remaining animal fibres, are cells much elongated. And he considers the same general plan to prevail in the animal and vegetable.* The approach of both of these observers to the truth is striking. Both, however, either failed to detect the nucleus or to attach any importance to it. They failed also to lay down a law of organic development. Hence their views were soon forgotten.

Since the discovery of the nucleus, by Dr. Robert Brown, in the vegetable cell, it had been recognized by many observers in various pathological, as well as healthy animal cells, and in the germ cell or ovule of birds, as early as in 1825, by Purkinje; while

* Dutrochet, op. citat.

Purkinje,* Valentin,† and Turpin‡ had actually called attention to the relations of the animal and vegetable cell to each other.

The preëxistence of the nucleus, and the gradual development of the cell about it, Valentin had attempted to demonstrate in the case of pigment cells, C. H. Schultz in the blood corpuscle, Rudolph Wagner in the egg, and Henle in epithelium, all before the work of Schleiden had appeared. Valentin, too, had said, when describing the nucleus of epidermic cells, that they reminded him of the nucleus of the cells of vegetable tissues.§ Not only this, but Armand de Quatrefages|| and Dumortier¶ had actually observed the origin of young cells from the full grown, in the embryo of the freshwater snail, while Valentin had furnished examples of the development of fibres out of cells in muscular fibre, and in the substance of the crystalline lens. In fact, as stated by Dr. Waldo J. Burnett, in his admirable paper,** Valentin "perceived the true physiological

* Purkinje, in Raschkow, Meletemata Circa Mammalium Dentium Evolutionem. Diss. Inaug., Wratis.: 1835, p. 12.

† Valentin, Ueber den Verlauf und die Enden der Nerven, aus den Nov. Act. Nat. Curios., vol. xvii: besonders Abgedruckt. Bonn: 1836.

‡ Turpin, Ann. d. Sci. Nat., 2. ser. vii, 207.

§ Valentin, Nov. Act., N. C., xvii, pt. I, p. 96.

|| Quatrefages, Annales des Sci. Nat., 2 ser. ii, p. 114.

¶ Dumortier, Annales des Sci. Nat., 2 ser. vii, p. 129.

** Burnett, W. J. The Cell; its Physiology, Pathology, and Philosophy, as deduced from original investigations. To which is added its history and criticism. A prize essay, read before the American Medical Association, and published in vol. vi of its Transactions. Philadelphia: 1853.

relations of cells as far as he well could without apprehending the grand fact that the nucleated cell is the fundamental expression of organic forms."

SCHLEIDEN AND SCHWANN.

It was reserved for Schwann to accomplish this master stroke in observation and generalization, through the intermediate results of Schleiden, without whose observations on vegetable structures, the true position of the cell would probably have remained undetected for some time longer. Schleiden, in 1838, clearly pointed out the formation of cells in vegetable structures, according to a single and uniform method, and elaborated the theory of development of which the cell was the unit, and which Schwann immediately extended to animal tissues.

A formidable obstacle for some time in the way of a law of development, applicable to animal and vegetable tissues, was the opinion, long entertained, that the growth of animals whose tissues are furnished with vessels is essentially different from that of plants; an independent vitality being ascribed to the elementary particles of vegetables growing without vessels. So firmly was this believed, that the ovum which exhibited undoubted evidences of an actual vitality at one period of its growth, was said by all physiologists to have had a plant-like growth. This obstacle was removed in 1837, by Henle,* who showed

* Henle, Symbolæ ad Anatomiam vill. intest. Berol.: 1837.

that an actual growth of the elementary parts of epithelium took place without vessels.

Taking up the nucleus as discovered by Robert Brown, Schleiden,* in reference to its function, applies the name cytoblast (κυτος, a cell, βλαστος, a bud or sprout), or "cell bud," and in a careful study of its anatomy, discovers that "in very large and beautifully developed cyloblasts, there is observed a small, sharply defined body, which, judging from the shadow which it casts, appears to represent a thick ring, or thick-walled hollow globule."† One, two, three, and even four of these may be present. Without further present comment than that these characters, as given by Schleiden, are by no means constant, it is plain that what is commonly known as the *nucleolus* is here intended, to the discovery of which we are therefore indebted to him, though Valentin also claims its discovery at an earlier period.‡ He further states that the observations he has made upon all plants, lead him to the conclusion that these small bodies are found earlier than the cytoblasts.

According to Schleiden, when starch is to be em-

* Schleiden, Beiträge zur Phytogenesis, Müller's Archiv, 1838, p. ii; Contributions to Phytogenesis, Sydenham Soc. Transl., p. 283.

† The term nucleolus or nucleus-corpuscle (Kernkorpörchen), seems to have been first applied by Schwann. (See Introduction to Schwann's Researches, Syd. Society's Translation.)

‡ Valentin, "Outline of the Development of Animal Tissues," in Wagner's Elements of Physiology, Translated by Dr. Willis. London: 1844, p. 214. Leipzig: 1839;—where he refers to Valentin's Repertorium, vol. i, p. 143.

ployed in new formations, it becomes dissolved into sugar or gum, which are convertible into one another. The sugar appears as a perfectly transparent fluid, not rendered turbid by alcohol, and receiving from tincture of iodine only so much color as corresponds to the strength of the solution. The gum is somewhat yellowish, more consistent, less transparent, and coagulated into granules by tincture of iodine, assuming a pale yellow color which is permanent. In further progress of organization, in which the gum is always the last fluid, a quantity of exceedingly minute granules appears in it, most of which, from their exceeding minuteness, appearing as black points. Here it is that organization takes place, though the *youngest* structures are composed of another distinct homogeneous, perfectly transparent substance—so transparent as to be invisible when not surrounded by opaque or colored bodies, —and continuing thus after pressure. This he calls vegetable gelatine, and considers as slight modifications, pectin, the basis of gum tragacanth, and many of the substances usually enumerated under the term vegetable mucus. It is this gelatine which is ultimately, through the agency of the nucleus, converted into the actual cell-wall, or structures which consist of it in a thickened state, and into the matter of vegetable fibre.

In this homogeneous *blastema* or *cytoblastema* (said to be most easily studied in the embryo sac, and in the extremity of the pollen tube), are very soon precipitated or developed *mucous* or protein *granules*, when the solution immediately becomes cloudy and more

or less opaque. Single, larger, more sharply defined, granules next become apparent, A, fig. 2, constituting the *nucleoli*, about which the smaller granules soon collect to form the *nuclei* or *cytoblasts*, B. These then grow considerably in the free state, C, but so soon as they have attained their full size, a delicate, transparent vesicle rises upon their surface, assuming the relation of the watch crystal to a watch, D, E. Thus is constituted the young cell. The vesicle gradually expands and becomes more consistent, and with the exception of the cytoblast, which always forms a portion of it, the wall now consists of gelatine. The entire cell then increases beyond the margin of the cytoblast, and quickly becomes so large that the latter at last merely appears as a small body inclosed on one of the side walls. In this manner, we have *exogenous free cell formation.* Within these cells, again, as well as in the homogeneous blastema about them, new cytoblasts arise, grow, and form young cells which grow and fill up the mother cells, and finally cause them to disappear. This is *endogenous cell formation.* According to Schleiden "the entire *growth* of the plant consists only of a formation of cells within cells." No other method

FIG. 2.

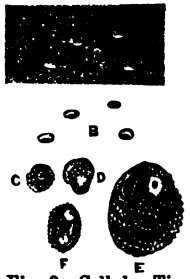

Fig. 2. Cellular Tissue, from the embryo sac of Chamaedorea Schiedeana, in the act of formation.

A, Formative substance, gum, mucous granules, nuclei of cytoblasts (nucleoli).

B, Cytoblasts.

C, Single and free cytoblast more highly magnified.

D, Cytoblast with cell forming in it.

E, Same more highly magnified.

F, Cytoblast isolated after destruction of cell.

From Schleiden — Beiträge zur Phytogenesis.

of formation of new cells seems to have been conceived by him. For although the multiplication of cells by fissiparous division of previously existing cells, had been demonstrated by Mirbel,* and confirmed by Von Mohl,† before the investigations of Schleiden had been made, the latter author considered the apparent growing across of the partition cells an illusion, and that the young cells escape observation in consequence of their transparency, until, at a late stage, their line of contact is regarded as the partition wall of the parent cell; while even Schwann states somewhat hesitatingly what is now so generally admitted.‡ This is the cell theory of Schleiden, which has also been properly called the theory of *free cell formation*, since it involves a spontaneous generation of the cell.

The merit of Schwann consisted in applying this theory to animal tissues, his conclusions being based upon the study of the formation of the chorda dorsalis, and cartilage, and a comparison of their cells with those of vegetable tissues. Thus, in a cytoblastema, either structureless or minutely granulous, "a nucleolus is first formed; around this a stratum of substance is deposited, usually minutely granulous, but not yet sharply defined on the outside. As new molecules are constantly being deposited in this stratum between those already present, and as this takes place within a precise distance of the nucleolus only,

* Mirbel, Recherches sur la Marchantia, 1833.

† Von Mohl, Entwicklung und Bau der Sporen der Kryptogam. Gew., Flora, 1833.

‡ Schwann, op. citat. Introduction, p. 4.

the stratum becomes defined externally, and a cell nucleus having a more or less sharp contour is formed. The nucleus grows by a continuous deposition of new molecules between those already existing, that is by intussusception. (See Fig. 3, *e.*) If this go on equally throughout the entire thickness of the stratum,

FIG. 3.

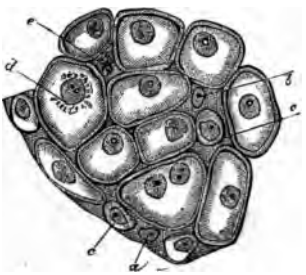

FIG. 3. From the point of a branchial cartilage of Rana esculenta. (From Schwann.)

the nucleus may remain solid; but if it go on more vigorously in the external part, the latter will become more dense, and may become hardened into a membrane, and such are the hollow nuclei."*

When the nucleus has reached a certain stage of development, the cell is formed around it. The following is the process by which this takes place:— "A stratum of substance, *which differs from the cytoblastema*, is deposited upon the exterior of the nucleus. (See Fig. 3, *d.*) In the first instance, this stratum is not sharply defined externally, but becomes so in consequence of the progressive deposition of new molecules. The stratum is more or less thick, sometimes homogeneous, sometimes granulous: the

* Schwann, op. citat., p. 175.

latter is most frequently the case in the thick strata which occur in the formation of the majority of animal cells. We cannot, at this period, distinguish a cell cavity and cell wall. The deposition of new molecules between those already existing proceeds, however, and is so effected that when the stratum is thin, the entire layer, and when it is thick, only the external portion, becomes gradually consolidated into a membrane. The external portion of the layer may become consolidated soon after it is defined on the outside; but, generally the membrane does not become perceptible until a later period, when it is thicker and more defined internally; many cells, however, do not exhibit any appearance of the formation of a cell membrane, but they seem to be solid, and all that can be remarked is that the external portion of the layer is somewhat more compact.*

"Immediately that the cell membrane has become consolidated, its expansion proceeds as the result of the progressive reception of new molecules between the existing ones; that is to say, by virtue of a growth by intussusception, while at the same time it becomes separated from the cell nucleus. . . . . The interspace between the cell membrane and the cell nucleus is at the same time filled with fluid, and this constitutes the *cell contents.* During this expansion the nucleus remains attached to a spot on the internal surface of the cell membrane." Though, according to Schwann, in animal cells the nucleus is never covered by a lamella passing over its inner surface, as is the

* Schwann, op. citat, p. 176.

case with the vegetable cell according to Schleiden. Thus is formed the animal cell according to Schwann, and although its method is identical with that of Schleiden, both as to endogenous and exogenous cell formation, we have quoted his own paper, because he is plainly fuller, and more precise in his descriptions. The object of each observer was, however, the same with regard to the tissues studied; the additional object of Schwann being to show that *all organisms, whether animal or vegetable, are formed on a common principle, and that this principle is origin from cells*,—that the various tissues of the plant and animal, however simple or complicated, are all combinations of these cells, modified in adaptation to the special peculiarities of tissues.

The conception of Schleiden was truly original, though its application was less difficult in consequence of the simplicity of vegetable tissues. The conception of Schwann was easier, in being the reflection of that of Schleiden, while its application was more difficult, in consequence of the great diversity of animal tissues; so difficult that he acknowledged that "there are some exceptions, or at least differences, which are as yet unexplained." This need not surprise us when we recollect that one of the ablest modern exponents of the cell theory, admits the difficulty of its application to some of the so-called higher tissues.* Indeed, the careful reader of Schwann's researches cannot but be surprised at the accuracy of the observations of this histologist, nor can he

* Virchow, Cellular Pathology, Chance's Translation. Am. Edit., Philada.: 1868, p. 78.

fail to realize how comparatively few have been the changes necessitated in his descriptions, or the method of application of his theory to the formation of the different tissues. Indeed, the portion of the theory of Schleiden and Schwann which does not accord with the latest expression of the cell doctrine, is not so much that which pertains to the formation of tissues from existing cells, as that which relates to the method in which they supposed the cells to originate; which, it will be recollected, was by a species of *spontaneous generation* of the essential parts of the cell, in a homogeneous cytoblastema.

A difference in the anatomy of the cell as given by Schwann, and physiologists of the present day is seen in the location of the nucleus by the latter, who places it not merely *eccentrically*, but actually "separated from the surface only by the thickness of the assumed cell-wall;"* though an inspection of Schwann's drawings would not convey this impression. At the present day, the situation of the nucleus, though usually central, is known to be not unvarying. Again, the primary and absolutely essential presence of the *nucleolus*, as well as the universal presence of the *cell-wall*, may be considered characteristics of Schleiden and Schwann's idea of the cell, which are now no longer insisted upon.

As already stated (p. 33), Schwann would seem to have admitted also, the formation of cells by division, though with some hesitation. Thus he writes:† "A mode of formation of new cells, differ-

* Schwann, op. citat., p. 37, a. f.

† Schwann, op. citat., Introduction, p. 4.

ent from the above-described, is exhibited in the multiplication of cells by division of the existing ones; in this case, partition-walls grow across the old cell, if, as Schleiden supposes, this be not an illusion, inasmuch as the young cells might escape observation in consequence of their transparency, and at a later stage, their line of contact would be regarded as the partition-wall of the parent cell."

It would be easy to point out other defects in the theory of Schleiden and Schwann, when it is tested by comparison with the more accurate observation of the last twenty-five years, none of which should be permitted to detract from the credit which attaches to the originators of this conception. It must not be forgotten, that it is no less true of science than of art, that great and important truths in their entirety, are gradually developed, and that no single mind is capable of elaborating them from their incipiency to their complete expression. And, since many clever people had daily noticed the rising of steam from the boiling kettle without thinking of utilizing its principle of expansion, so many careful observers had time and again witnessed the cellular or vesicular composition of plants, and yet failed to appreciate the importance of the nucleated cell, and to deduce from it a law of development applicable to all organic forms. Again, as the engine of Watt was far different from the beautiful and powerful creation of the mechanic of the present day, so the cell theory, as developed by Schleiden and Schwann, has been further evolved by later histologists. So that we may truthfully reiterate, with Prof. Huxley,

"whatever cavillers may say, it is certain that histology before 1838, and histology since then, are two different sciences—in scope, in purpose, and in dignity—and the eminent men to whom we allude, may safely answer all detraction by a proud '*circumspice.*'"*

According to these observers, then, a perfectly-formed cell would be defined as a *closed vesicle*, with certain contents, among which were *essentially* a *nucleolus* and *nucleus.*

HENLE, 1841.

It is not consistent with our object to include all of the numerous observations which were multiplied after this period, incited by the researches of Schleiden and Schwann. It is simply to point out the salient features of those results which point towards, and have culminated in accepted views. It has been stated that previous to Schleiden's researches, in 1838, the formation of cells by *division* had been asserted as one mode of origin of cells, that Schleiden had declared this an error of observation, and that Schwann had hesitatingly, if at all, accepted it as a rare method of cell formation.

Henle,† who, in general, adopted the view of Schwann as to the *primary origin* of cells, though he made exception to its universality of application, says that cells *multiply* in three ways:

1. By *budding* (durch Sprossen), as in certain lower plants.

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* Huxley, op. cit., p. 290.

† Henle, Allgemeine Anatomie. Leipzig: 1841, p. 172 et seq.

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2. By *endogenous* cell development (durch endogene Zeugung), where the cell contents of the mother cell become the cytoblastema of the daughter cells, as originally given by Schleiden and Schwann.

3. By *division* or *segmentation* (durch Theilung), of which he says, however, no examples are found among animals; though he also states in the paragraph* immediately following, "We would, with Schwann, consider cell formation in the yolk, by 'furrowing,' an analogous process, if we may consider the yolk as a simple cell." He then proceeds to describe how, by a "cording in"† of the surface, the yolk is divided into two equal parts, these into four, and so on until the entire yolk becomes a *mulberry mass*, made up of little round bodies. This segmentation of the ovum already observed in the yolks of frogs, fish, molluscs, and medusæ, Henle says at this time (1841), has perhaps merely escaped notice‡ in the case of the higher animals, as plausibly suspected by Bergman,—a suspicion which we need scarcely say was amply confirmed a little later. But Henle also states, in the same connection, that certain cases arise in which perfect cells are developed in a cytoblastema, in a manner which is inexplicable, and that from these cells, tissues are finally developed.§ Whence the undetermined state of the question

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* Henle, op. cit., p. 176.

† Einschnüren, to cord (a box, &c.), to bind with a cord, to string. *Grieb.*

‡ Henle, op. cit., p. 177.

§ Henle, op. cit., p. 177.

at that time may be easily inferred.* Nor is mention here made by Henle, of the nucleus of the cell, as the primary seat of the segmentation. The surface of the cell is said to be "corded in," or "furrowed," deeper and deeper, until the division takes place. This description is still adhered to by many physiologists of the present day, who consider that there is a simple disappearance of the germinal vesicle or nucleus of the ovum after fecundation, rather than a division of it into two, and substitution of these for the original one.

* While endeavoring to trace out the steps by which the present most generally accepted views with regard to the origin of cells, were arrived at, it must not be forgotten that other dissenting views were also advanced, though tending differently from those incorporated in the text, where it is desired more particularly to trace those culminating in existing doctrines. Thus did Reichert[1] early (1840), dissent from Schwann, since he failed to find the nucleus universally present in the yolk. Karsten[2] (1843), published a dissertation upon the cell, in which he stated that cells originate without a pre-existing nucleus, and by the expansion of amorphous granules of organic matter; and more recently (1863), the same author practically reiterates this view, since he says that all "cells of vegetables originate as minute *free vesicles* in the fluid contents of previously existing cells," and regards the nucleus as a "small tertiary cell, retarded in its development."[3] Again, "when the nucleus is present, the origin of new cells is quite independent of it."[4] In addition to the statement contained in the text, Henle also (1843), alleged that some of the so-called fibrous tissues were "formed by the aggregation of granules in a certain way without the intervention

[1] Reichert, Das Entwickelungslebun im Wirbelthierreich. Berlin: 1840, pp. 6, 93.

[2] Karsten, De Cella vitâle Dissertatio. Berlin: 1843.

[3] Karsten, Ann. and Mag. of Nat. History, vol. xiii, p. 268. London: 1864.

[4] Karsten, Ann. and Mag. Nat. History, vol. xiii, p. 281.

MARTIN BARRY, 1840.

It was in his first series of embryological researches, published in Part II, of the "Philosophical Transactions" of London, for 1838, p. 310, that Dr. Martin Barry declared "that the germinal vesicle (which he regarded as the nucleus), and its contents constitute throughout the animal kingdom the most primitive portion of the ovum." In his second series, Part II, 1839, in stating that the germinal vesicle returns to the centre of the cell, *post coitum*, he first pointed out that the nucleus does not always accompany the cell through the whole vital process at the periphery (the original position according to Schleiden and Schwann), but that it also passes to the centre, as we now well know. Here, also, he declares, but in his third series, Part II, 1840, he *demonstrates* that there arise in the parent vesicle, two or more infant vesicles, the parent vesicle disappearing by liquefac-

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of true nucleated cells."[1] Kölliker,[2] one of the foremost exponents of the cell doctrine of the present day, in 1844 expressed his dissent from the idea of unity in the mode of cell formation, and states that if there is a single method of cell formation which is invariable, it remains to be discovered. Mr. Paget,[3] so well known from his Lectures on Surgical Pathology, suggested in 1846, that a cell might arise in some other way than from a nucleus, since he had met morbid growths composed entirely of fibres, in which *not* a nucleated cell was present. Most of which statements are, however, reconciled by the information which has since been added to our knowledge of the subject.

[1] Henle, Traité d'Anatomie Générale. Trad. d'Allemand, par A. J. Jourdain, 2 vol. Paris: 1843, tom. 1, p. 374.

[2] Kölliker, Entwickelungsgeschichte der Cephalapoden. Zurich: 1844.

[3] Paget, Report on the Progress of Anatomy and Physiology. Br. and For. Med. Rev., July, 1846.

tion. And in his third series, p. 529, he says, "The germinal vesicle does not burst, or dissolve away, or become flattened on or before the fecundation of the ovum as hitherto supposed. It ceases to be pellucid." And on page 531, "The germinal vesicle fills with cells, and these become filled with the foundations of other cells; so that the germinal vesicle is gradually rendered opaque."

He also describes in this series, in great detail, the mode in which these cells are produced from the germinal *spot*, which he considers in the light of a nucleus to the germinal vesicle. Part II, 1839, p. 360. And though the minute details may not precisely accord with those of the most recent observations, the correct idea is clearly grasped. In fact, it may be said that in minuteness of detail alone does he differ from later observers, and had he simply stated that the young cells arise from the nucleus or nucleolus of the parent cell, he would accord precisely with the most recent observers. But he is, if possible, even more explicit when he says, "The process inherited from the germinal vesicle by its offspring, reappears in the descendants of these. Every cell, whatever its minuteness, if its interior be discerned, is filled with the foundations of new cells, into which its nucleus has been resolved." Again he says,* "Schleiden has seen the nucleus undergoing such changes (division), but failed to recognize them." And finally, in "Philosophical Transactions" for 1841, pp. 207–8, we have the following striking paragraphs, which would seem also to correct some previous errors:

* Barry, Philosophical Transac., 1840, p. 348, § 385.

"§ 77. I am very much inclined to believe, that in the many instances in which authors on 'cells' have described and figured more than one nucleolus in a nucleus, there has been either an incipient division of the nucleus into discs, or the nucleus has consisted of two or more discs; the nucleoli of those authors having been the minute and highly refracting cavities or depressions in the discs. If this has really been the case, it affords additional evidence, I think, *that reproduction of cells by the process I have described—namely, division of the nucleus of the parent cell—is universal*—so numerous have been the instances in question. I may refer to the figures given by Schwann, who examined nearly every tissue, and to those of Schleiden, whose observations have been so extensive on plants. I think, indeed, that many of the figures of Schwann afford evidence of the division in question having taken place. It is to be recognized in his delineation of the cells of cartilage, cellular tissue, middle coat of the aorta, muscle, tendon, the feather, &c. The same remark is applicable to a figure given by Reichert of ciliated epithelium cells. Dr. Henle found that in the layers of his 'pflaster-epithelium' cells, the nucleus, very distinct in the lower cells, had almost disappeared in those situated in the upper part. From this observation, and from the presence of two nucleoli in some of the nuclei figured by this observer, as well as from the nucleus becoming more granular, I think it extremely probable that these cells (including those of the epidermis), are reproduced by the process just referred to—*division of the nucleus;* additions being

no doubt continuously made at the lower part of the layer, by 'which cells previously there are pushed farther out.'

"§ 83. The nuclei which various observers have found lying among the fibres of various tissues, have been considered by them as the 'remains of cells.' This may have been the case, but so far from thinking with those observers, that the nuclei in question were 'destined to be absorbed,' I am disposed to consider that they were sources from which there would have arisen new cells."

Without doubt, we can say, as did Goodsir,* in the above by Martin Barry, we have the "first consistent account of the development of cells from a parent centre, and more especially of the appearance of centres within the original sphere." Nothing more definite, or directly to the point, could be desired, and we think it may be justly said of Barry, that he completed the expression of the cell theory inaugurated by Schleiden and Schwann, in modifying the mode of origin to conform to most recent observation.

PROF. JOHN GOODSIR, 1845.

In 1845, Prof. John Goodsir published his paper on "Centres of Nutrition,"† in "Anatomical and Pathological Observations," in which he clearly grasped the two important principles of the modern Cellular Pathology; *first*, the *activity* of these centres

* Goodsir, Turner's Edition of Anatomical Memoirs. Edinburgh: 1868. Note on p. 390.

† Goodsir, op. citat., p. 389.

(nuclei), their power "to draw from the capillary vessels, or from other sources, the materials of nutrition, and to distribute them by development to each organ or texture after its kind;" *second*, the *origin* of such centres or nuclei from previously existing nuclei. In this short paper of three pages, are contained, as stated, the essentials of the cell doctrine of Virchow, and as it has recently assumed additional interest on controversial* grounds, it may be well to introduce as much as bears directly upon the subject. "The centre of nutrition with which we are most familiar, is that from which the whole organism derives its origin—the germinal *spot* of the ovum. From this, all the other centres are derived, either mediately or immediately; and in directions, numbers, and arrangements, which induce the configuration and structure of the being. As the entire organism is formed at first, not by simultaneous formation of its parts, but by the successive development of these from one centre, so the various parts arise each from its own centre, this being the original source of all the centres with which the part is ultimately supplied.

"From this it follows, not only that the entire organism, as has been stated by the authors of the cellular theory, consists of simple or developed cells, each having a peculiar independent vitality, but that there is in addition, *a division of the whole into departments*, each containing a certain number of developed cells, *all of which hold certain relations*,

* Edinburgh Monthly Medical Journal, Feb. and April, 1869, pp. 766 and 959.

to one central or capital cell, around which they are grouped. It would appear that from this central cell, all the other cells of its department derive their origin. It is the mother of all those within its own territory. It has absorbed materials of nourishment for them while in a state of development, and has either passed them off after they have been fully formed, or have arrived at a stage of growth when they can be developed by their own powers.

"Centres of nutrition are of two kinds,—those which are peculiar to the textures, and those which belong to the organs. The nutritive centres of the textures are in general permanent. Those of the organs are in most instances peculiar to their embryonic stage, and either disappear ultimately or break up into the various centres of the textures of which the organs are composed.

"*A nutritive centre, anatomically considered, is merely a cell, the nucleus of which is the permanent source of successive broods of young cells*, which from time to time fill the cavity of their parent, pass off in certain directions, and under various forms, according to the texture or organ of which their parent forms a part."

Prof. Goodsir does not fail to state in the first paragraph of his paper, that with many of these centres anatomists have been for some time familiar, but further remarks that with few exceptions they have looked upon them as embryonic structures. He alludes in a note to the observations of Bowman and Barry, the former on "Muscle," and the latter "On the Corpuscles of the Blood," in Philosophical

Transactions, respectively, of 1840 and 1841, and states in a second note that "for the first consistent account of the development of cells from a parent centre, and more especially the appearance of new centres within the original sphere, we are indebted to Martin Barry."* We have carefully read the references in each instance. In Bowman's paper† we can recognize a brief reference to a possible influence of the cell upon nutrition, but none as to its origin, in the following sentence: "It is, however, not impossible, that in all these cases, there may be during development, and subsequently, a further and successive deposit of corpuscles (nuclei) from which both growth and nutrition may take their source." That Dr. Barry's paper is more explicit has been shown.

HUXLEY, 1853.‡

Allusion has already been made to Prof. Huxley

* Goodsir, Anatomical Memoirs, vol. ii, p. 389, and note on pp. 390–91.

† Bowman, "Muscle," Philos. Transac., 1840, pt. i, p. 485.

‡ We presume it will scarcely be inferred by any reader, that the views of Prof. Huxley here presented are brought forward as those now entertained by the learned Professor, and with which the public have been made so generally familiar through his lecture on "Protoplasm," or the "Physical Basis of Life," delivered at Edinburgh, November 18th, 1868, and originally published in the "Fortnightly Review" for February, 1869; but also largely republished in numerous English and American periodicals, as well as in a separate pamphlet, to be had of the publishers of the Yale College Courant, New Haven, Conn. To one closely observing, however, we think that these later views will appear to be foreshadowed in the theory here given, and which we think of sufficient historical importance to justify its presentation here.

in connection with Wolff, of whose theory he has been the able exponent. In the same paper* he has given us his own views—"conceived in the spirit, and not unfrequently borrowing the phraseology, of Wolff and Von Baer." We present them, as far as may be consistent with brevity, in his own words:

"Vitality, the faculty, that is, of exhibiting definite cycles of change in form and composition, is a property inherent in certain kinds of matter. There is a condition of all kinds of living matter in which it is an *amorphous germ*—that is, in which its external form depends merely on ordinary physical laws, and in which it possesses no internal structure. Now, according to the nature of certain previous conditions, the character of the changes undergone, or the different states exhibited—or, in other words, the successive differentiations of the amorphous mass will be different.

"The *morphological* differentiation may be of two kinds. In the lowest animals and plants,—the so-called unicellular organisms—it may be said to be *external*, the changes of form being essentially confined to the outward shape of the germ, and being unaccompanied by the development of any internal structure.

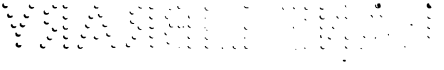
"But in all other animals and plants, an internal morphological differentiation precedes or accompanies the external, and the homogeneous germ becomes separated into a certain central portion, which we have called the *endoplast*, and a peripheral portion,

* Huxley, Review of the Cell Theory. Br. and For. Med.-Chir. Rev., Oct., 1853, p. 305.

the *periplast.* Inasmuch as the separate existence of the former necessarily implies a cavity in which it lies, the germ in this state constitutes a vesicle with a central particle, or a 'nucleated cell.' *There is no evidence whatever* that the molecular forces of the living matter (the 'vis essentialis' of Wolf, or the vital forces of the moderns), are by this act of differentiation localized in the endoplast to the exclusion of the periplast, or vice versa. *Neither is there any evidence that any attraction or other influence is exercised by the one over the other;* the changes which each subsequently undergoes, though they are in harmony, *having no causal connection with one another*, but each proceeding, as it would seem, in accordance with the general determining laws of the organism. On the other hand, the 'vis essentialis' appears to have essentially different and independent ends in view, in thus separating the endoplast from the periplast.

"The *endoplast* grows and divides; but, except in a few more or less doubtful cases, it would seem to undergo no other morphological change. It frequently disappears altogether; but as a rule it undergoes neither chemical nor morphological metamorphosis. So far from being the centre of activity of the vital actions, it would appear much rather to be the *less important histological element.*

"The *periplast*, on the other hand, which has hitherto passed under the name of cell wall, contents and intercellular substance, is the subject of all the most important metamorphic processes, whether morphological or chemical, in the animal and plant. By its differentiation, every variety of tissue is pro-



duced; and this differentiation is the result, *not of any metabolic action of the endoplast*, which has frequently disappeared before the metamorphosis begins, but the intimate molecular changes in its substance, which take place under the guidance of the 'vis essentialis,' or, to use a strictly positive phrase, occur in a definite order, we know not why.

"The metamorphoses of the periplastic substance are twofold — *chemical* and *structural*. The former (*chemical*), may be of the nature either of *conversion*,— change of cellulose into xylogen, intercellular substance, &c., of the indifferent tissues of embryos into collagen, chondrin, &c.,—or of *deposit*,—as of silica in plants, of calcareous salts in animals. The *structural* metamorphoses, again, are of two kinds, *vacuolation* or the formation of cavities, as in the intercellular passages of plants, the first vascular canals of animals — and *fibrillation*, or the development of a tendency to break up in certain definite lines rather than in others."

These views he illustrates by examples from vegetable life in the *sphagnum* leaf, and from animal life in *connective tissue* and striped *muscle*.

As characteristic and distinguishing features of this theory, we desire to point out, first, the substitution of the term "*endoplast*" for "nucleus;" that of "*periplast*" for "cell wall," and "intercellular," "substance." Second, the absolutely passive nature of the "endoplast," which is neither itself the author of changes, nor the subject of changes. Third, the passive nature as well, of the "periplast," so far as it is the author of changes, though it is pre-

eminently the *subject* of changes, the *seat in which changes take place.* And herein, we believe Huxley to have been misinterpreted by some who have presented his views elsewhere, as Dr. Beale,* who represents him as believing the periplast active, that it is the efficient agent, that it sends in partitions, &c. But that Prof. Huxley considered it passive we believe may be legitimately inferred from his text. As the *seat* of change, however, accomplished not as "the result of any metabolic action of the endoplast, but of intimate molecular changes in its substance, which take place under the guidance of the *vis essentialis,*" the *periplast* is differentiated into every variety of tissue. Finally, we have the distinct admission, as seen in the sentence last quoted, and also throughout the entire expression of the theory, of a controlling, guiding principle, through which the differentiation is accomplished. This principle, which is here referred to as the "vis essentialis," is elsewhere included under the expressions "vitality," and "general determining laws of the organism." Though this admission is seemingly so at variance with the views of the same observer at the present date (1870), who in common with other physicists emphatically denies the existence of "vital force," or even such a thing as life itself, yet, as already intimated, we deem it possible to detect a foreshadowing of his more modern views, in the follow-

* Beale, Microscope in Medicine. Third Edition. London: 1867, page 147. Beale, Structure and Growth of the Tissues. London: 1865, pp. 9, 10.

ing paragraph of the paper whence we have derived our information:

"We have therefore maintained the broad doctrine established by Wolff, that the vital phenomena are not necessarily preceded by organization, nor are in any way the result or effect of formed parts, but that the faculty of manifesting them resides in the matter of which living bodies are composed, as such—or, to use the language of the day, that *the vital forces are molecular forces.*"*

Huxley moreover says that the three botanical data upon which Schwann's theory was based, viz.:

1. The anatomical independence of the vegetable cell as a separate entity,

2. His conception of the structure of the vegetable cell, and

3. Its mode of development, were all erroneous.

Since first, he (Huxley) considers that the fact that by certain chemical or mechanical means, a plant may be broken up into vesicles, corresponding with the cavities which previously existed in it, is of no more value in proving the independence of these vesicles, than the fact that a rhombohedron of spar, broken up with the hammer, into minute rhombohedrons, is evidence that those minuter ones were once independent, and formed the larger by their coalescence.

Second, Schwann's view of the anatomy of the cell was incorrect, since he regarded the nucleus as invariably present, whereas in certain vegetable cells

* Huxley, loc. citat., p. 314.

(as in Hydrodictyon, Vaucheria, Caulerpa, Sphagnum), it is indubitably absent; and since he did not include the nitrogenous primordial utricle, discovered by Mohl, in 1844,* as one of the elements of the cell.

Finally, Schwann's mode of cell-development is erroneous, having "been long since set aside by the common consent of all observers;" cell-development always occurring by *division*, except in the embryo sac of the Phanerogamia, the sporangia of Lichens, and of some Algæ and Fungi; and even the free cell-development of the latter is quite different from that of Schleiden and Schwann, being by the development of a cellulose membrane (periplast) around a mass of nitrogenous substance (endoplast), which may or may not contain a nucleus.

The difference between the views of Schwann and Huxley are best expressed by the latter in the contrast he draws between those of Schwann and Wolf: "For Schwann, the organism is a beehive, its action and forces resulting from the separate but harmonious action of all its parts. For Wolff (and Huxley), it is a mosaic, every portion of which expresses only the conditions under which the formative power acted, and the tendencies by which it was guided."

The statements of Prof. Huxley with regard to *cell-development* entirely accord with the most recent observations on the subject, and are quite important to us in tracing out the present state of the cell doctrine.

* The existence of the primordial utricle is denied by many botanists of the present day.

J. HUGHES BENNETT, 1855.*

Dr. Bennett, of Edinburgh, considers that "the ultimate parts of organization are not cells nor nuclei, but the minute molecules from which these are formed. They possess independent physical and vital properties, which enable them to unite and arrange themselves so as to produce higher forms. Among these are nuclei, cells, fibres, and membranes, all of which may be produced directly from molecules. The development and growth of organic tissues is owing to the successive formation of histogenetic and histolytic molecules. The breaking down of one substance is often the necessary step to the formation of another; so that the histolytic or disintegrative molecules of one period become the histogenetic or formative molecules of another."

Again: "As to development, the molecular is the basis of all the tissues. The first step in the process of organic formation is the production of an organic fluid; the second, the precipitation in it of organic molecules, from which, according to the molecular law of growth, all other textures are derived either directly or indirectly."†

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* Bennett's Practice of Medicine. Am. Ed. of Wm. Wood & Co., N. Y.: 1866, p. 118.

Prof. Bennett has further elaborated his views in the Edinburgh Medical Journal, March, 1868, and The Popular Science Review, January, 1869, but his conclusions are substantially the same as quoted.

† Op. citat., p. 119.

Figs. 4, 5, 6, 7, illustrate these views amply.

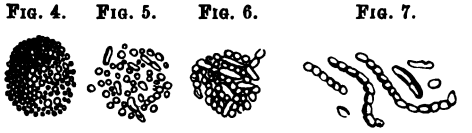

Fig. 4, Molecular structure of the scum on its first appearance, in a clear animal infusion. Fig. 5, Molecular structure of the same six hours afterwards. The molecules are separated, and the long ones (so-called vibriones) in active movement. Fig. 6, The same on the second day. Fig. 7, Filaments (so-called spirilla) formed by aggregation of the molecules, in the same scum on the third and fourth days, all in rapid motion. 800 diam. linear. (From Bennett's Practice.)

Prof. Bennett contends, also, that morbid growths may easily be shown to originate in a molecular blastema, though not to the exclusion of pre-existing cells. The accompanying figures are sufficiently explanatory.

Fig. 8, Nuclei imbedded in a molecular blastema. Fig. 9, Young fibre-cells formed by the aggregation of molecules around the nuclei of Fig. 8. Fig. 10, Cancer cells, one with a double nucleus. Fig. 11, Histolytic or so-called granule-cells, breaking down from fatty degeneration. 250 diam. linear. (From Bennett's Practice.)

It should be stated also, that this author in common with others not accepting the cell doctrine in its entirety, admits the production of cells by buds, division, or proliferation, without a new act of generation, and that "this fact comprehends most of the

admitted observations having reference to the cell doctrine."*

We have in the expression of this theory, a practical admission of the spontaneous origin of animal life, of which Dr. Bennett, in the paper referred to in the Popular Science Review, for Jan., 1869, openly declares himself the advocate.

Closely allied to this theory is the so-called investment or cluster-theory (Umhüllungs-theorie), described by Virchow on page 53, of Cellular Pathology, (Am. Ed. of Chance's Translation); according to which "originally a number of elementary globules existed scattered throughout a fluid, but that under certain circumstances they gathered together, not in the form of vesicular membranes, but so as to constitute a compact heap, a globe (mass, cluster—Klümpchen), and that this globe was the starting-point of all further development, a membrane being formed outside and a nucleus inside, by the differentiation of the mass, by apposition, or intussusception."

Fig. 12.

Fig. 12. Diagram of the Investment (cluster) theory. *a*, Separate elementary granules. *b*, Heap of granules (cluster). *c*, Granule cell, with membrane and nucleus.

TODD AND BOWMAN, 1856.

Notwithstanding earlier approximations to the

* Op. citat., p. 123.

truth, we find free cell formation still admitted by the eminent authorities Todd and Bowman, as one mode of origin of cells, so late as December, 1856, though the spontaneous origin of organs is spoken of as exceedingly doubtful. After describing the elements of the ovum, considered in its entirety as a nucleated cell, and referring to the period after fecundation, it is stated, "At this period the embryo consists of an aggregate of cells, and its further growth takes place by the development of new ones. This may be accomplished in two ways; first, by the development of new cells within the old, through the subdivision of the nucleus into two or more segments, and the formation of a cell around each, which then becomes the nucleus of a new cell, and may in its turn be the parent of other nuclei; and, secondly, by the formation of a granular deposit between the cells, in which the development of the new cells takes place. *The granules cohere to each other in separate groups, here and there, to form nuclei, and around each of these a delicate membrane is formed, which is the cell membrane.* The nuclei have been named *cytoblasts*, because they appear to form the cells; and the granular deposit in which these changes take place is called the *cytoblastema.*

"In every part of the embryo the formation of nuclei and of cells goes on in one or both of the ways above mentioned, and, by and by, ulterior changes take place, for the production of the elementary parts of the tissues."*

* Todd and Bowman, The Physiological Anatomy and Physiology of Man. Am. Edit., Philadelphia: 1857, p. 63.

Thus did physiologists adhere to the original free cell formation of Schleiden and Schwann. Singularly, Dr. Carpenter,* who expressly states, in his Manual of Physiology, edition of 1865, that he has been led to the view of Professor Beale by comparison of the results of the recent inquiries of several British and Continental histologists with those of his own studies, says, a few pages further on (p. 150), "New cells may originate in one of two principal modes; either directly from a previously existing cell, or by an entirely new process in the midst of an organizable blastema." He then proceeds to give the two methods in detail, without in any way denying the latter.

VIRCHOW, 1858.

Less than two years later, August 20th, 1858, Prof. Virchow published his "Cellular Pathology as based upon Physiological and Pathological Histology." According to him, the cell is the only possible starting-point for all biological doctrines. This cell can only originate from a previously existing cell, taking its primary origin from the ovum, and the Harveian maxim *omne vivum ex ovo*, becomes in its special application, *omnis cellula e cellulâ*. This is true of all physiological and pathological processes in the vegetable and animal. In all editions of "Cellular Pathology" which we have met, the typical cell is described as consisting essentially of "cell wall,"

* Carpenter, Manual of Physiology, London: 1865. Note on p. 14.

"cell contents," and "nucleus;" the "nucleolus," though usually met in fully developed older forms, is not considered an essential constituent of the cell. The object of the "nucleus," according to Virchow, is entirely connected with the *life* of the cell, that which maintains it as an element and which insures its reproduction. While to the "cell contents" over and above the nucleus, that is the "residual cell contents," is due the *function* of the cell, that to which is due the contractility of muscle, the neurility and sensation of nerve, and the secretory office of the gland cell.*

To secure the universal application of the cell doctrine, it becomes necessary to eliminate from the vegetable cell, the external non-nitrogenous membrane known as cellulose, and restrict it to the nitrogenized portion comprised in the *primordial utricle* as the *proper cell wall*, and in the *protoplasmic* contents of the cavity as the proper cell contents, which contain also the nucleus. "It is only when we adhere to this view of the matter, when we separate from the cell all that has been added to it as an after-development, that we obtain a simple, homogeneous, extremely monotonous structure, recurring with extraordinary frequency in living organisms."†

More recently, however, Virchow is reported as not regarding the "cell wall" as an essential part of the cell, as stated in Cellular Pathology; but *that a*

* Virchow, Cellular Pathology as based upon Physiological and Pathological Histology. Second Edition. Translated by Frank Chance, M.B., &c. Am. Edition, Philadelphia: 1863, p. 37.

† Op. cit., pp. 31, 34.

nucleus surrounded by a molecular blastema was sufficient to constitute a cell; then he says that the outer part of this cell blastema consolidates and forms a cell wall as Beale has shown, and that this takes place in the amœba when placed in water.*

As thus defined, the cell is the seat of pathological and physiological processes rather than the blood, or the nerves. The cell is active,—the ultimate morphological element in which there is any manifestation of life, and beyond which the seat of real action cannot be removed. Hence the term *Cellular Pathology* rather than humoral, or neural, or solidistic. The so-called *exudations* are not such in the strict sense of the term, and the cells which they contain, whether of pus or organizable lymph, are the result of proliferation of previously existing cells. Even "fibrin, wherever it occurs in the body external to the blood, is not to be regarded as an excretion from the blood, but as a local production," resulting from the activity of the cells of the tissue in which it is found, and conveyed to the surface by the transudation of the *serous* fluids alone.† In the above statements we have the first distinctive feature of Virchow's theory.

Again, since every organized body is usually made up of a number of these cells, each independent in itself, yet combined and arranged for the attainment of a special end, and therefore mutually dependent, there result certain communities or cell territories into which the body is portioned out by Virchow.

* Letter from Berlin, in Edinburgh Medical Journal, February, 1865.

† Virchow, op. cit., pp. 435–6.

But not only is the relation of these cells to each other and to the central cell whence they took their origin mutually dependent, but in many animal tissues, at least, we have the so-called *intercellular substance* in a certain definite manner dependent upon the cell or cells which it surrounds, "so that certain districts belong to one cell and certain others to another." Especially is this the case in pathological processes, where sharp boundaries may often be drawn between cell territories. Herein have we the second distinguishing character of Virchow's theory.

There are also a third and fourth distinctive features. It has already been explained that the principle of the theory of Schleiden and Schwann lay in this, that every tissue, healthy or morbid, results from the apposition of cells, and that this principle is still observed as correct, the mode of origin of the primary cell being alone the object of dispute. According to Virchow, however, it is a special cell which becomes the starting-point of physiological and pathological processes, and by its various metamorphoses constitutes the healthy or morbid tissue, excepting epithelial formations. This cell is the so-called *connective tissue corpuscle*, or cell of the connective tissue, which, according to Virchow, is a cell with all its essential constituents (cell wall, cell contents, and nucleus), and not a nucleus alone, as originally described by Schwann, and later by Henle* and Landois.† From the well-known universal

* Henle, Bericht über die Fortschritte d. Physiol., 1859; 1866, p. 41.

† Landois, Zeits. f. wiss. Zool., Bd. xvi, p. 1.

prevalence of connective tissue, this view receives support. Thus, it is from the connective tissue corpuscles of the soft, silk-like connective tissue, so universally present in muscle, that the muscular fasciculi are primarily developed. It is from these that nerve fibres take their origin. It is by the rapid proliferation of these corpuscles that pus is formed,

FIG. 13.

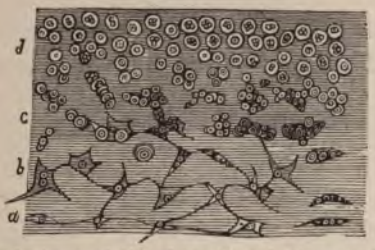

Fig. 13. Purulent granulation from the subcutaneous tissue of a rabbit, round about a ligature. *a*, Connective tissue corpuscles. *b*, Enlargement of the corpuscles with division of the nuclei. *c*, Division of the cells (granulations). *d*, Development of the pus corpuscles. x300. (From Virchow.)

FIG. 14.

Fig. 14. Interstitial purulent inflammation of muscle in a puerperal woman. *m m*, Primitive muscular fibres. *i i*, Development of pus corpuscles by means of the proliferation of the corpuscles of the interstitial connective tissue. x280. (From Virchow.)

(Figs. 13 and 14); it is from the perverted growth and development of these that tubercle and cancer

Fig. 15.

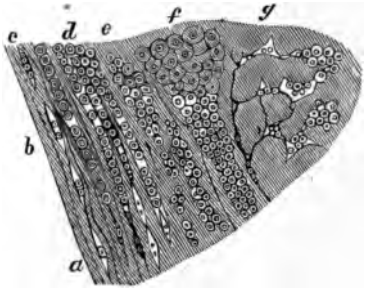

Fig. 15. Development of cancer from connective tissue in carcinoma of the breast. *a*, Connective tissue corpuscles. *b*, Division of the nuclei. *c*, Division of the cells. *d*, Accumulation of the cells in rows. *e*, Enlargement of the young cells and formation of the groups of cells (foci, Zellenheerde), which fill the alveoli of cancer. *f*, Further enlargement of cells and groups. *g*, The same development seen in transverse section. (From Virchow.)

arise (Fig. 15), and similarly all pathological new formations. None of these products are exudations from the blood, according to Virchow. They are entirely local in their origin. In these views he is supported by the majority of German observers.

Another mode of formation of pus is however admitted by Virchow, in the growth and development of new cells in *epithelium*, whether in cuticle or mucous membranes. Whether forms of suppuration exist which may be referred to muscular, nervous, and capillary elements, he considers doubtful.

A fourth and final distinctive feature of Virchow's views, concerning which there is less unanimity, even among German histologists, is his peculiar system of

canals or tubes, produced by the anastomosis of one cell with another, and which he considers must be classed with the great canalicular system of the body, as forming a supplement to the blood and lymphatic vessels, and as filling up the vacancy left by the old vasa serosa which do not exist.* (See Fig. 16.) Of

FIG. 16.

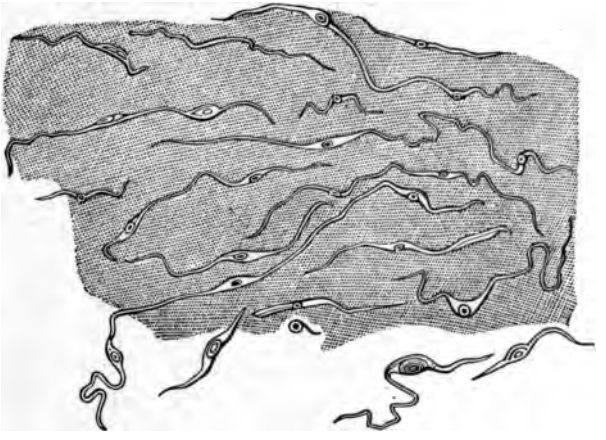

Fig. 16. Connective tissue from the embryo of a pig after long-continued boiling. Large spindle-shaped cells, connective tissue corpuscles (Bindegewebeskörperchen), some isolated and some still imbedded in their basis substance, and anastomosing one with the other. Large nuclei with their membrane detached; cell contents in some cases shrunken. x350. (From Virchow.)

this system he also considers the cord-like fibres of yellow elastic tissue as forming a part.† These he considers, with Donders,‡ as originating by a trans-

* Virchow, op. citat., p. 76.

† Virchow, op. citat., p. 133, a. f.

‡ Donders, Siebold und Kölliker's Zeitschrift, Bd. iii.

formation of the connective tissue corpuscles themselves. He says, "The transformation of these latter into the former, can gradually be traced with such distinctness, that there remains no doubt, that even the coarser elastic fibres directly result from a chemical change and condensation of the walls themselves.* Where originally there lay a cell, provided with a delicate membrane and elongated processes, there we see the membrane gradually increasing in thickness and refracting the light more strongly, whilst the proper cell contents continually decrease and finally disappear.

FIG. 17.

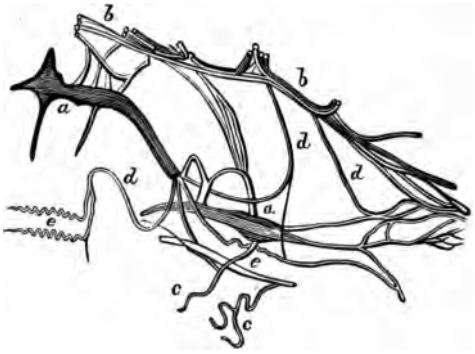

Fig. 17. Elastic networks and fibres from the subcutaneous tissue of the abdomen of a woman. *a a*, Large elastic bodies (cell bodies), with numerous anastomosing processes. *b b*, Dense elastic bands of fibres on the border of larger meshes. *c c*, Moderately thick fibres spirally coiled up at the end. *d d*, Finer elastic fibres, at *e* with more minute spiral coils. x300. (From Virchow.)

"The whole structure becomes in this way more

* Virchow, op. citat., p. 133.

homogeneous, and to a certain extent sclerotic, and acquires an incredible power of resisting the influence of reagents, so that it is only after long-continued action that even the strongest caustic substances are able to destroy it, whilst it completely resists the caustic alkalies and acids in the degree of concentration usually employed in microscopical investigation. The farther this change advances, the more does the elasticity of the parts increase, and in sections we usually find these fibres, not straight or elongated, but tortuous, curled up, spirally coiled, or forming little zigzags (Fig. 17, *c*, *e*). These are the elements which by virtue of their great elasticity, cause retraction in those parts in which they are found in considerable quantity, as, for example, in the arteries. The fine elastic fibres, which are those which possess the greatest extensibility, are usually distinguished from the broader ones, which certainly do not present themselves in tortuous forms. As regards their origin, however, there seems to be no difference between the two kinds; both are derived from the connective tissue cells, and their subsequent arrangement is only a reproduction of the original plan. In the place of a tissue, consisting of a basis substance and anastomosing reticulated cells, there afterward arises a tissue with its basis substance mapped out by long elastic networks with extremely compact and tough fibres." This may be looked upon as the least well-determined of the important points of Virchow's doctrine, though most German histologists also favor it. Among these may be

classed Kölliker,* C. O. Weber,† Leydig,‡ Friedreich,§ His,‖ Donders,¶ Wittich,** Böttcher,†† Billroth,‡‡ and Stricker. They are opposed by Schwann, Reichert, and Henle, and find little favor among English and American histologists.

A part of this system, also, according to Virchow, are the so-called dentinal tubules, the lacunæ and canaliculi of bone, even the continuity traced by Gerlach,§§ between the ciliated cells of the aqueduct of Fallopius; that by Heidenhain‖‖ and Brücke¶¶ between the lacteals and cylinder epithelium of the intestinal villi of the rabbit, by means of corpuscles of connective tissue; in the epithelium of the endocardium by Luschka;*** and the results of similar observations by Eckhart,††† Billroth,‡‡‡ and Friedreich.§§§

* Kölliker, Manual of Human Microscopic Anatomy, p. 41. 1860. Also recent paper in which he completely assents to Virchow's views, according to N. Y. Q. J. Pschy. Med., July 1869.

† Weber, C. O., Virchow's Archiv, Bnd. xiii–xv.

‡ Leydig, Handbuch der Histologie. 1856.

§ Friedreich, Virchow's Archiv, Bd. xv.

‖ His, Beitrage zur Normalen in Pathol. Histol. d.Cornea.

¶ Donders, loc. citat.

** Wittich, Virchow's Archiv, Bd. ix.

†† Böttcher, Virchow's Archiv, Bd. xiii.

‡‡ Billroth, in Beitrage zur Pathol. Histol., 1858, admits all but the tubular nature of the processes.

§§ Gerlach, Mikrosk. Studien. 1858.

‖‖ Heidenhain, Moleschott's Untersuchungen, Bd. iv, 1858, p. 251.

¶¶ Brücke, Moleschott's Untersuchungen, Bd. viii, 1862, p. 495.

*** Luschka, Virchow's Archiv, Bd. ix, p. 569.

††† Eckhart, Beitrage Anat. und Physiol. 1855.

‡‡‡ Billroth, Müller's Archiv, 1858.

§§§ Friedreich, loc. citat., p. 538.

The other fibrous element of areolar or connective tissue, which forms the mass of its bulk, the *pure white fibrous* or waving, does not, according to Virchow, have its origin in cells, but is a modification of a previously homogeneous intercellular substance, deposited between the cells,—a view which in its glaring departure from the primary proposition that the cell is the starting-point, and that every tissue is composed of cells or some modification ot cell forms, presents one of the few inconsistencies traceable in the theory of Virchow.

We think it proper, in a historical memoir of this kind, to refer to some severe critical remarks which appeared in the Edinburgh Medical Journal of February and April, 1869, in which Prof. Virchow is accused of appropriating the observations of Prof. Goodsir as his own. That there are points in common, it will be recollected, and, also, that these are first, the invariable origin of cells from previously existing cells, and second, the division of the tissues into cell territories. Now on the one hand we deem that the dedication of Virchow's volume to Prof. Goodsir is as handsome an accredit as could possibly be given for whatever of common there may be in the writings of the two authors, and on the other hand we have seen that Martin Barry is acknowledged even by Goodsir, to be the author of the "first consistent account of the development of cells from a parent centre." The idea of *cell territories* seems, however, to have originated with Goodsir, nor do we believe, for the reason stated, that Virchow intended to usurp his prerogative. The merit of Virchow consists in

his application by actual demonstration of the first of these points to so large a variety of physiological and pathological processes, to which is added original conception in the prominence given to the connective tissue corpuscle and the canalicular system, whatever may be the truth with regard to either.

SARCODE OF DUJARDIN. PROTOPLASM OF MAX SCHULTZE. 1835–61.

Dujardin* had, in 1835, discovered in the lower animals a living, moving, contractile substance, which he called *sarcode.* The peculiar appearances of this substance attracted the attention of many observers, among whom were Meyen,† Huxley, Max Schultze, John Müller, and others, who thought it peculiar to the lower animals, and there was assigned to it a property of "irritability without nerves."‡

The observation of Siebold,§ that the yolk globules of Planaria exhibit contractions and expansions, which with suitable care continue for hours, and the discoveries which followed of similar movements and changes in form, led Kölliker‖ to express the conjecture that the contents of all cells are contractile. Virchow¶ attributed the movements to a contractile

* Dujardin, Ann. d. Sciences Nat., tom. iii et v.

† Meyen, Einschlägige Liter, in E. Hæckel's Die Radiolaren. 1862.

‡ Schultze, Max, Organis. d. Polythalamien. 1854.

§ Siebold, Froriep's Notizen, Nr. 380, p. 85.

‖ Kölliker, Wurzb. Verh., Bd. viii.

¶ Virchow, Archiv, Band v.

substance. Leydig* considered the movements of the yolk globules as phenomena of life, and Kuhne† had studied physiologically and chemically, sarcode and muscular tissue, and compared the irritability and changes after death, of both. But all considered sarcode as something different from the animal cell, as a body *sui generis*. Max Schultze, in 1861,‡ had first shown this analogy between sarcode and the contents of the animal cell, and that the entire infusorial world, simple or compound, is made up of cells, thus extending the typical formative element of Schwann to the entire organized creation. So much for the relation of sarcode to the animal cell.

The comparison between sarcode and the protoplasm of plants was undertaken by Unger,§ E. Brücke,‖ E. Hæckel,¶ Max Schultze,** and W. Kuhne,†† and by their efforts, according to Stricker,‡‡ our knowledge of the independent life of the cell was extended, in a very short space of time, further than in the twenty years previous.

Unger§§ (1855), had been struck with the close

* Leydig, Handbuch der Histologie. 1856.

† Kuhne, Müll. Archiv., 1859, p. 817.

‡ Schultze, Max, Müll. Archiv, 1861, p. 17.

§ Unger, Anatomie und Physiology d. Pflanzen. 1855.

‖ Brücke, E., Elementarorganism, Wien Sitzungsb. 1861.

¶ Hæckle, E., Radiolaren. 1862.

** Schultze, Max, Protoplasm der Rhizopoden und der Pflanzenzellen. 1863.

†† Kuhne, W., Protoplasm und die Contractilitat. Lpzg.: 1864.

‡‡ Stricker, S., Handbuch der Lehre von den Geweben des Menschen und der Thiere. Leipzig: 1868, p. 3.

§§ Unger, op. citat., p. 280.

similarity of the mobile phenomena of the Polythalamiæ with those of the processes of protoplasm stretched across the cavity of many vegetable cells. Although he had not personally investigated the former, he became convinced from Schultze's description, that a resemblance amounting to identity existed between their movements and the protoplasm streams of vegetable cells."*

Shortly before this, Pringsheim† (1854), showed that no such membrane as a primordial utricle existed, but that *all within* the *cellulose* wall of the living vegetable cell was *protoplasm* and cell fluid, however complex its composition.

"He admitted that in the cortical layer of the protoplasma a distinct arrangement into layers often occurred, and these he distinguished as the cutaneous and granular layers of the protoplasma, but he denied that the primordial utricle could be differentiated as a membrane from the subjacent protoplasm. If, in animal cells, partly from their relatively small size, and partly from their greater average wealth in protoplasma, it is more rarely possible to make a sharp demarcation between a cortical layer of protoplasm and a cell fluid, there nevertheless exists a difference in the constitution of the former, such that a cutaneous layer, destitute of, or scantily supplied with granules, incloses the remaining more granular material. The white blood-cell may serve

* Duffin, A. B., On Protoplasm. Quart. Jour. Mic. Sci., N. S., vol. iii, 1863, p. 252.

† Pringsheim, Untersuchungen über d. Bau. u. d. Bildung d. Pflanzenzelle. 1854.

as an example. This is, however, very different from a proper membrane."*

The name *protoplasm* for the contents of the animal cell had already been brought into use by Remak.

Leydig,† in 1856, claimed for the contents of the cell a higher dignity than for the membrane or cell wall. He claimed that a *cell was but protoplasm* (klumpchen-substanz) *inclosing a nucleus.* The cell membrane, according to him, was simply the hardened periphery of the substance of the cell.

To Max Schultze, however, belongs the credit of having fully overturned the vesicular idea of cells. In 1861,‡ he insisted upon some modification of prevailing views, respecting the relation of cell wall to cell contents, and contended for a higher position for that part of the cell corresponding to the protoplasm of Von Mohl (that within the so-called primordial utricle), and showed how a careful study of the phenomena, presented by the pseudopodia extended by the various Rhizopods, might aid in clearing up the life of the elements of the cell.

He also defined the cell as "*protoplasm surrounding a nucleus.*" The importance of this definition, as stated by Stricker,§ lay not so much in the fact that many cells were denied a cell wall, as that the so-called cell contents could now be made to harmonize

* Duffin, loc. citat., p. 252.

† Leydig, op. citat.

‡ Schultze, Max, Ueber Muskelkörperchen, in Reichert and Dubois Reymond's Archiv, 1861.

§ Stricker, op. citat., p. 5.

with the animal primordial substance or sarcode. Schultze illustrates his definition by the embryo cells resulting from the segmentation of the ovum, as typical cells, which are thus composed of protoplasm surrounding a nucleus, which nucleus, as well as protoplasm, are products of like constituent parts of another similar cell. "The cell leads in itself an independent life of which the protoplasm is especially the seat, although to the nucleus also undoubtedly falls a most important, though not yet precisely determined role. Protoplasm is for the most part no further distinct than that it will not commingle with the surrounding medium, and in the peculiarity that with the nucleus it forms a unit. Upon the surface of the protoplasm, there may form a membrane, which, *although derived from it, may be chemically different*, and the assertion that it *is the beginning of a retrogression may be defended.* A cell with a membrane can not divide itself, unless the protoplasm within the membrane divides itself. A cell within a membrane chemically different from protoplasm, is like an encysted infusorium."*

Brücke† went even further in his definition, and said that it was not shown that the nucleus even is an essential element of the cell. In proof of which he adduces the cells of cryptogams. Facts in justification of Brücke's doubt are adduced by Stricker‡ in the discovery by Max Schultze,§ in the Adriatic

* Schultze, Max, Protopl. d. Rhizopoden. Leipzig: 1863.

† Brücke, E., Die Elementarorganismen, p. 18–22. 1861.

‡ Stricker, op. citat., p. 6.

§ Schultze, Max, Organis. d. Polythalam. 1854.

Sea, of a non-nucleated amœba, by Hæckel* in the Mediterranean, of a non-nucleated protozoon (Protogenes primordialis), and by Cienkowsky† of two non-nucleated monads, namely, Monas amyli and Protomonas amyli. Hæckel says of his Protogenes primordialis that it multiplies by division. Stricker's‡ own observations on the fecundated egg of the frog, incline him to adopt the view of Brücke, and to omit the nucleus in a theory of elementary organization.§

With these general considerations in the history of "protoplasm," we are the better prepared to take up the theory of

DR. BEALE, 1861.

In April and May, 1861, Prof. Lionel S. Beale delivered the lectures before the Royal College of Physicians, of London, in which he promulgated

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* Hæckel, Zeitschr. f. w. Zoolog., 1865, Bd. xv.

† Cienkowsky, Max Schultze's Archiv, 1865.

‡ Stricker, op. citat.

§ In a recent paper by Prof. Hæckel,[1] he states that the "protoplasm theory" was brought forward in its elementary form by Cohn,[2] in 1850, and by Unger, in 1853. It was further developed in 1858, and finally completely established in 1860, by Max Schultze. Hæckel also considers that by no phenomena is the correctness of this theory so thoroughly proved, and at the same time in so simple and unassailable a manner, as by the vital phenomena of the Monera, by the processes of their nourishment and reproduction, sensitiveness and motion, which entirely proceed from one and the same very simple substance, a true "primitive slime."

[1] Hæckel, Ernst, Monograph on the Monera, and Remarks on the Protoplasm Theory. Q. Jour. Mic. Sci., Apr., July, and Oct., 1869.

[2] Cohn, F., Nachträge zur Naturgeschichte des Protococcus pluvialis; Nova Acta Ac. Leop. Carol., vol. xxii, pars ii, p. 605. 1850.

the views which have since been further elaborated and become permanently associated with his name. These views were published, in part, in Beale's "Archives of Medicine," and in September, 1861, in a volume "On the Structure of the Simple Tissues of the Human Body," in the preface to which he says "he thinks it right to state that the conclusions which have now assumed a definite form have gradually grown upon him during the course of observations, extending over a period of several years. In fact some of the drawings in this volume, and others which have been published elsewhere, equally favorable to this view, were made long before any specific theory had been arrived at."

The "*cell*," or "*elementary part*," as Dr. Beale prefers to call it, is composed of matter in two states, matter which is *forming*, and matter which *is formed;* matter which has the power of *growing* by producing matter like itself *out of pabulum* or food, and matter which possesses no such power, but results from the death of the forming matter. The former is known as *germinal* or *living* matter, the latter as *formed* matter. The former, in varying quantity in different cells, is *central* in its situation (see Plate, Fig. 17), and includes what has been called by others nucleus, cell contents, protoplasm, endoplast. The latter, also present in different quantity in different cells, is *peripheral* (Plate, Fig. 17), and includes what is known as cell wall, periplast, intercellular substance, and products of secretion.

In its structural characters, germinal matter is *soft*, *transparent*, *colorless*, and as far as can be determined

by the highest powers, *structureless*, being visible only through its difference in refracting power as compared with the menstruum in which it floats, or by the granular matter it may entangle; and these characters are the same at every period of its existence. They may be studied in the simplest vegetables, in the thallus of the sugar fungus, among the lowest animals, in the amœba (Plate, Fig. 16), and in higher animals in the mucous, pus, or white blood corpuscles (Plate, Fig. 10), all of which are composed almost purely of germinal matter; the very thin periphery of formed material being scarcely appreciable or distinguishable from the diffraction band.

In its *endowments* and *properties*, germinal matter is *acting*, *living*, *growing*, and *moving*, through some inherent power of its own. It alone, as stated, is capable of producing material like itself out of pabulum, and multiplying by division, or a dropping off of a portion of itself, which portion immediately assumes an independent existence, and grows, maintains, and reproduces itself like the parent germinal matter. It is also capable of being stained by an ammoniacal solution of carmine, and the younger it is, or more recently formed, the deeper is the stain it assumes. And since the latest formed always appears in the centre of the mass, successive tints, or zones of color, will often be produced in the staining process, growing deeper from without inward, as seen in Fig. 17 of Plate.

It has been stated that what is called nucleus by Virchow and others, is included in germinal matter. This is true, though the nucleus is not always the

whole of the germinal matter. There may be other older germinal matter beyond the nucleus, on its way to conversion into formed material, but still germinal matter, which assumes a tint with carmine, but not so deep as the nucleus. Thus, the entire mass of the pus corpuscle (Plate, Fig. 10), except its extreme periphery, is germinal matter, yet there is within this another younger portion of germinal matter, taking a deeper tint with carmine, but which alone of the elements of this cell, we are in the habit of calling "nucleus." The "*nucleus*," then, is nothing but a *new centre* of germinal matter, and the "*nucleolus*" is a younger centre. And there may even be within this, a still younger portion of living matter, taking even a deeper stain, which might be called a "*nucleoleolus*." By this staining process may we distinguish the nucleolus from a minute oil-drop often mistaken for it, and which will not assume any tint.

On the other hand, germinal matter in a comparatively quiescent state is often quite destitute of nuclei. But let the mass be freely supplied with nutrient matter and nuclei and nucleoli rapidly make their appearance.

So with regard to the "cell contents" over and above the nucleus, although they may all be germinal matter, yet this is not necessarily the case. Thus in the white blood corpuscle and mucous corpuscles, what Virchow would consider cell contents is all germinal matter; but the superficial epithelial cell lining the interior of the mouth has its nucleus alone composed of germinal matter, and much that has been de-

scribed as cell contents is really formed matter. (Figs. 5 and 6 of Plate.) More nearly does the germinal matter of Beale* correspond with the "protoplasm" of Max Schultze, with which, indeed, it seems identical, except that the latter observer seems somewhat at a loss how to dispose of the nucleus, of which he does not speak as a new or young centre of protoplasm.

Formed material, instead of being *active*, so far as the vital acts described as characteristic of germinal matter are concerned, is *passive*, *non-acting*, *dead*, and can only increase at the expense and death of the germinal matter, on the periphery of which it is formed. It differs widely in its appearance, and is often "structured" as in muscle and nerve, but not necessarily so, as is seen in the intercellular substance of hyaline cartilage. It possesses also certain properties, different in different situations, and widely different also from those of germinal matter. Thus it is contractile in the sarcous tissue of muscle, exhibits neurility in the nerve, is protective in epithelium, is diffluent as the formed material of the milk-cell (milk), and in the formed material of the liver-cell (bile). Again, it is hard and elastic in the intercellular substance of cartilage, and epidermis, horn and nails. It does not become stained on being soaked in weak solution of carmine in ammonia, and if by reason of the strength of the solution it should happen to be stained, the color will wash out on soaking in glycerine, which is not the case with the coloring of the germinal matter.

* Beale, Protoplasm; or, Life, Force, and Matter. London: 1870, p. 38.

The cause of this permanent staining of the germinal matter by an ammoniacal solution of carmine, is thought by Dr. Beale to be due to an acid reaction of this matter, in consequence of which the carmine is precipitated from its alkaline solution. This view would seem to be confirmed by the researches of Ranke on the Reaction of the Tissues.

The *size* of the elementary part, as thus composed, is extremely various. The smallest particles of germinal matter, measured by Dr. Beale, are less than $\frac{1}{10000}$ of an inch in diameter, and would not be called cells in the ordinary sense of the word, yet they are functionally such; that is, they grow, multiply by division, and under appropriate circumstances assume the characters of fully formed cells. On the other hand, the largest epithelial cells, including their germinal matter and formed material, are often as large as the $\frac{1}{250}$ of an inch in diameter, or larger; cells of morbid growths are sometimes $\frac{1}{200}$, while the human ovum, which is a typical cell, varies from the $\frac{1}{240}$ to $\frac{1}{120}$ of an inch. Pure germinal matter is rarely seen in masses as large as the $\frac{1}{500}$ of an inch in diameter, without breaking up into smaller particles of germinal matter, and as constituting the nuclei of fully formed cells, is usually from $\frac{1}{8000}$ to $\frac{1}{3000}$ of an inch in diameter.

The *method of production of formed* material is best studied in the epithelial structures, particularly in the epithelium lining mucous cavities, of which sections may be easily made down to the vessels whence their nourishment is obtained. In the deep layers, next the nutrient surface, the cells will be found to

consist of almost pure germinal matter (Plate, Fig. 1), imbedded in a soft, mucus-like, yet continuous formed matter. These masses of germinal matter divide and subdivide, pushing the older masses towards the surface, to make up for those which are constantly exfoliated. While this is going on, however, the germinal matter keeps increasing in size until the cells arrive half way towards the surface, by absorption of nutrient pabulum, which has to work its way through any formed material already existing. At the same time, a portion of the germinal matter is being converted into formed material, which accumulates on its surface, within that already formed, stretching it, and becoming more or less incorporated with it. *Thus, both constituents of the cell increase up to a certain point, the cells constantly growing in consequence.* As new cells are, however, produced from below, the older ones are removed farther and farther away, the formed matter becoming more and more impervious to nutrient pabulum. At length a point is attained when the entire cell ceases to increase in size, since no pabulum reaches the masses of germinal matter, though the latter is still being converted into formed material. Hence, the masses of germinal matter actually grow smaller, as the cell increases in age; and when the periphery is reached, there remains but a small nucleus of germinal matter, with a large quantity of formed material. Thus, we are enabled to judge of the age of the cell by the relative quantity of germinal matter and formed material; if the former be large, and the latter small, the cell is young, whereas, if the opposite relation

exists, the cell is old, and almost ready to exfoliate. But exfoliation probably does not take place until the last particle of germinal matter dies, and the entire cell becomes a mass of passive, lifeless, formed material.

The production of formed material from germinal matter, may also be studied in the conversion of the white blood-corpuscle into the red. In the spring of the year, many white corpuscles can be found in the blood of the frog and newt, undergoing conversion into formed material at their edges, where the usual granular appearance is being substituted by the smooth and slightly colored. This goes on until all except the nucleus is thus converted. In mammalia this change goes on until the whole white corpuscle is thus converted into the red.

Secondary Formed Material.—There are certain kinds of formed material, to which this term is applied by Dr. Beale. These are the oil of the fat cell or vesicle, and the starch granule of the vegetable cell. It results, as does all formed material, by a conversion of the germinal matter into this special form. The young fat cell, as all young cells, is almost pure germinal matter; as it grows older, however, and is exposed to oxidizing influences, the conversion of germinal matter takes place, partly into the cell wall proper of the fat vesicle, and partly into the secondary formed material or oil, until finally, it becomes a mere dot on the inner surface of the cell-wall, or disappears altogether.

The increase of cells, according to Beale, takes place in several ways; *every cell coming from a pre-existing*

cell, but the germinal matter is always the portion in which it originates.

There is not generally a symmetrical division of the nucleus into two, and these into four, as is so often described, and as is often seen in the vegetable cell, but there is rather a budding, and subsequent dropping off of the portions of germinal matter which is to produce the new cell, and which almost always assumes the spherical form when allowed to float freely. (See Figure 10 of Plate.) The formed material is never active, but entirely passive in the process of cell multiplication.

Nutrition of Cells.—So, too, in the nutrition of the cell, the germinal matter is the sole active agent. The formed material may act as a filter to the nutrient matter, but is quite passive. The pabulum, which is coursing through the bloodvessels, becomes converted into germinal matter, which in turn becomes formed material, and so long as this is kept up, the cell continues to grow. The course taken by the pabulum, and the order of conversion, is shown by the arrows, in Figure 17, of Plate, and will be readily understood by reference to the explanation. Occasionally, and especially in disease, the formed material may become the pabulum for rapidly multiplying cells, and thus be consumed.

Intercellular substance has already been spoken of as formed material. We have it most strikingly present in the white fibrous tissue, or tissue of tendons, and in hyaline cartilage. If the former be stained by carmine, and examined in thin section under the microscope, it will be found composed of beautiful

bands of gently waving fibrous tissue, or tissue exhibiting a fibrous appearance, at varying intervals in which are noted nuclear masses of germinal matter, which have assumed the tint of carmine. Or, if dilute acetic acid be added to the specimen, the fibrous appearance will at once become homogeneous, while the nuclei will be rendered distinct, and clearly visible. In young tendon (Plate, Figure 11), the masses of germinal matter will be found very abundant, and the intercellular fibrous substance in smaller quantity than in old tendon where the masses of germinal matter occur only at long intervals. These masses of germinal matter, or connective tissue corpuscles, it will be recollected, are considered by Virchow as perfect cells, presenting cell wall, cell contents, and nucleus, and the fibrous intercellular substance as a subsequent modification of a homogeneous matrix, dropped between the cell by the bloodvessels. These connective tissue corpuscles are regarded by Beale as simple masses of germinal matter, the conversion of which into formed material produces the fibrous intercellular substance, as seen in Figure 11, Plate, and between which and the intercellular substance immediately adjoining, there is no line of separation, constituting a cell wall.

As the tendon grows older, the masses of germinal matter become less abundant, because a larger number have been totally converted into formed material; and the bands of indestructible material which sometimes join them, and which are considered by Virchow as a part of his canalicular system, are, according to Beale, *nothing but imperfectly converted formed material*,

or rather germinal matter, which has not been converted. While the twisted and curling cord-like fibres of the so-called *yellow elastic tissue*, also considered by Virchow as a part of his canalicular system, are thought by Beale to be composed in part of true yellow elastic tissue, such as is found in the ligamentum nuchæ, and likewise formed from nuclei (Plate, Figure 14), but in part also of the remains of nerves, and vessels, which were active at an earlier period of life.*

So, also, with *hyaline cartilage*. According to Beale, the intercellular substance results from the conversion of the so-called cartilage corpuscles or cells into formed material, and here also the germinal matter is directly continuous with the matrix, no proper cell wall intervening.

Cartilage is not to be considered as a distinct class of tissue from epithelium, nor can the latter, in all cases be distinguished from cartilage by the existence of separate cells, since in many forms of epithelium, at an early period of existence, the formed material corresponding to the masses of germinal matter is continuous throughout, and presents no indication of division into cells.† A "cell," or elementary part, then, of fully formed tendon or cartilage, would consist of a portion of germinal matter, with a proportion of formed material about it, extending to a line midway between that mass of ger-

* Beale, On the Structure and Growth of the Tissues, and on Life. London: 1865, pp. 95, 96, and 101.

† Beale, Protoplasm; or, Life, Force and Matter. London: 1870, p. 51.

minal matter and the masses immediately adjacent, of which the cartilage or tendon is composed; and such a line would correspond to the outer part of the surface of an epithelial cell.* In very young cartilages, as in very young epithelium, the cells consist of germinal matter only, with a small quantity of soft formed material intervening; and to understand the true relation of the cells to the intercellular substance, the tissue should be studied at different periods of its growth.

So, too, a "cell" or elementary part of muscle or nerve, would consist of a mass of germinal matter (the so-called nucleus), with a portion of muscular or nervous tissue corresponding with it, and with which it is uninterruptedly continuous.

In the formation of the *contractile tissue of muscle*, the germinal matter seems to move onward, undergoing conversion at its posterior part, into the muscular tissue, while it maintains itself by absorbing and converting pabulum. This will be understood by reference to Fig. 13. The fibres of *yellow elastic tissue* are formed in precisely the same manner. (See Plate, Fig. 14.) *Nerve fibres*, which in their completed state consist almost wholly of formed material, are similarly produced. In the young state, the fibre is composed of masses of germinal matter, linearly arranged, and in close proximity. As the conversion takes place and the fibre is produced, these become more widely separated, and the *tissue* resulting from such conversion is nerve. (Plate, Fig. 15.)

* Beale, Protoplasm, pp. 51–2.

The "Cell" or "Elementary Part" in Disease.

Here, as in normal nutrition, the germinal matter is alone active. It is impossible to state precisely every instance, but it is probable that in the majority of cases of disease, the morbid state consists essentially in a modification of the healthy nutrition of the cell, that is, the cell is made to grow more or less rapidly, or is perverted in its mode of growth, though it is likely that within certain limits, the conditions under which cells ordinarily live may be modified without deviation from health. But in *inflammatory* processes attended by local products, as *pus* or *lymph*, and in the production of *tubercle* and *cancer* we see the results of excessive multiplication and perversion of germinal matter consequent upon the appropriation of an *excess of nutrient pabulum*. In other instances, as *cirrhosis*, where there is shrinking, and hardening, and wasting, we see the effects of a diminished supply of pabulum, either through a diminution in the quantity supplied, or an impermeability in the septum through which it is compelled to pass.

An increased supply of pabulum may be admitted to germinal matter, either in consequence of the removal of barriers through which it is ordinarily compelled to pass, or in consequence of the nature of the fluids by which it is bathed. A simple illustration is seen in suppuration in epithelium, or the germinal matter of any tissue; for, according to Beale, suppuration and morbid processes generally, are not restricted to any one kind of ger-

minal matter, as the connective tissue corpuscle, but may occur in all germinal matter to which the conditions are supplied. Using epithelium by way of illustration, as the result of the increased supply of pabulum, the germinal matter first grows, as seen in Plate, Figs. 7 and 8, then in the luxuriance of its growth, even at the expense of the formed matter, sends out buds or processes, which soon drop off and become separate pus corpuscles. (Figs. 9 and 10.) These are produced so rapidly that there is not time for formed material to form upon their surface in any quantity, and they have not time, therefore, to pass on into epithelium. Hence pus corpuscles are almost pure germinal matter. So soon as the process ceases, in consequence of the supply of pabulum being diminished, the germinal matter multiplies less rapidly; opportunity is permitted for the production of formed material on its periphery, and the cell now passes through the different grades of epithelium, as described on pages 80, 81, and 82. The pus corpuscles are analogous to the deepest layers of epithelial cells there referred to, which deep cells are in fact the "mucous corpuscles," so-called, well known to be morphologically identical with pus corpuscles; the former being simply the young epithelial cell on its way to become perfect epithelium, while the latter is the same also, though never allowed to pass into the perfectly formed state.

Again, in *pneumonia*, and here we note where the paths of Virchow and Beale separate more widely, the so-called "exudation," or product which fills up the vesicular portion of the lung, considered by

Virchow a *local* one, the result of a proliferation of the connective tissue corpuscle of the part, and having no dependence upon the blood, is regarded by Beale as the result of a proliferation of *minute particles of germinal* matter (very much smaller than white blood corpuscles), which have passed out through the capillary walls with the liquor sanguinis.

In all inflammatory processes and fevers, this is believed by Dr. Beale to take place to a greater or less extent, the little masses of germinal matter or nuclei in the capillary walls also taking part, often increasing in size to such degree that they materially obstruct the passage of the blood, and by dropping off portions give rise to bodies floating in the blood precisely similar to white blood corpuscles, or pus corpuscles; indeed, Dr. Beale considers that this may be one of the sources of origin of the white blood corpuscle.*

So, also, *tubercle* is believed by Dr. Beale to result either from the multiplication of masses of germinal matter which have passed through the capillary walls from the blood, or from the masses of germinal matter usually termed nuclei, in connection with the capillary walls. He says, in illustration, "In a case of tubercle, which was very rapidly developed upon the surface of the pia mater, in a man of tubercular constitution, I proved most distinctly, that the tubercles were connected with the vascular walls, and that if the nuclei had not given origin to them, they were cer-

* Beale, Microscope in Clinical Medicine, 3d ed. London: 1867, p. 166.

tainly implicated. My own opinion is, that these nuclei gave origin to the tubercle corpuscles, in consequence of receiving from the blood peculiar nutrient matter. In the lung I have seen appearances which point to a similar conclusion."* Would not these views arise from appearances precisely analogous to those represented as giving support to the view, that tubercle originates in the perivascular sheaths of bloodvessels? The views of Beale, H. Charlton Bastian,† and Cornil,‡ would then constitute simply different modes of expression of the same truths.

ROBIN, F. A., POUCHET,§ 1867.

Robin, who may be considered the mouthpiece of the French school of histologists, reduces the human body to elementary parts, usually microscopic, which he calls *anatomical elements*. The forms he makes threefold,—*fibres*, *tubes*, and *cells*.

The *fibres* are generally of considerable length, sometimes extending from the lower part of the

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* Microscope in Clinical Medicine, 3d ed., 1867, p. 205.

† Bastian, H. C., Tuberc. Meningitis. Edinb. Med. Jour., 1867, p. 875.

‡ Cornil, Tubercle in Connection with the Vessels. Archiv. de Phys. Norm. et Path., Jan. et Fev., 1868.

§ Our information with regard to M. Robin's views, is derived from an admirable exposition of them published in vol. iv, 1867, of the New York Medical Journal, by Dr. Wm. T. Lusk, who there states that he has them mainly from a course of familiar and private instruction, furnished to him by M. C. H. Georges Pouchet, son of the eminent physiologist, Prof. F. A. Pouchet, Assistant to M. Robin, Lecturer upon Anatomy and Histology to the Ecole Pratique, author of "Un Précis d'Histologie," &c.; so that they may be said to be the views also of the elder Pouchet.

spinal cord to the extremity of the foot. Their diameter is, however, small, often not exceeding .001 millimetre, or .00003987 of an inch.

The *tubes* offer as objects of study the walls and the cavity.

The *cells* of *vegetables* have a wall, a cavity, and contents (air, oil, &c.). The *cells* of *animals*, on the contrary, are, as a rule, homogeneous. Animal cells containing a cavity are only found exceptionally. The substance of cells is ordinarily granular. Most cells contain an ovoid nucleus more granular than the substance itself.

In all cells the nuclei afford different chemical reactions from those of the substance of the element. Each cell is an independent organism, passing through various stages of development, from birth to death.

The birth (origin) of the elements takes place by 1st, segmentation; 2d, genesis; 3d, epigenesis; 4th, germination.

1st. *Segmentation.*—The human ovum is a small hollow sphere, containing in its interior the vitellus or yolk, which consists of granular matter in a hyaline substance. At the end of a certain time *particles of the granular matter approximate, unite and form a nucleus in the vitellus.* Next, the nucleus elongates, takes an hour-glass form (biscuit), then divides. The division of the yolk occurs simultaneously. In the same way, the division takes place into 4, 8, 16, and more parts. These divisions of the vitellus have received the name vitelline globules. Their mode of formation is called segmentation.

2d. *Genesis.*—When the vitelline globes have be-

come very small by successive segmentation (diameter .008 millimetre, .00031396 of an inch), these little bodies take the name of *embryonic cells.*

According to M. Robin, these cells dissolve. From the fusion results a blastema, in the midst of which nuclei make their appearance. This is known as *genesis.* It is the second and most frequent mode of the formation of anatomical elements. It is characterized by the appearance of an anatomical element in a fluid termed blastema, in which the element did not previously exist.

3d. *Epigenesis.*—When the embryonic cells dissolve, the embryo-plastic nuclei are produced by *genesis* in the blastema which results from their fusion. Then little cone-like prolongations of transparent matter are observed at the extremities of the nuclei, giving rise to the *fusiform* bodies, which are the *connective tissue corpuscles.* This mode of formation by growth upon another element is known as *epigenesis,* and is the mode in which connective tissue is developed. The prolongations of these fusiform bodies constitute the non-elastic fibres or white fibrous tissue element of connective tissue. Sometimes the substance deposited by epigenesis upon the nucleus has several prolongations, forming a *stellate cell* or connective tissue corpuscle. These fusiform and stellate cells are likewise known as *embryo-plastic* or *fibro-plastic bodies,* and this latter term is a most common one in French histology.

The *elastic fibres* of connective tissue are likewise formed by epigenesis, but upon special nuclei, and the prolongations are insoluble in acetic acid.

There is an early period of fœtal life, previous to the formation of connective tissue, in which we find only embryo-plastic nuclei and fusiform bodies in amorphous matter. This is called embryo-plastic tissue. Growth at this epoch is most rapid, the fœtus reaching in a short space of time the dimension of .030 millimetre (.0118 of an inch).

4th. *Germination.*—This is very frequent in vegetables, but in animals only one example is known, viz., at a period previous to the fecundation of the ovum. Before segmentation takes place the vitellus is observed to retract. The hyaline substance pushes out a prolongation, which becomes round, separates, and constitutes an independent anatomical element exterior to the vitellus, and bearing no part in the future development of the ovum.

The following account of certain special elements illustrates and further explains the views of M. Robin. *Red blood globules* (hematies), diameter, .007 millimetre ($\frac{1}{3500}$ of an inch); thickness .002 millimetre ($\frac{1}{12500}$ of an inch). Blood globules are elastic,—a property enabling them to elongate, and pass through capillaries which have a calibre less than the diameter of the blood globule. They are homogeneous throughout—i. e., *have no cell wall. Blood globules are formed by genesis in the blood plasma.* In the fœtus they make their appearance before the white blood globules (leucocytes). In man there are two kinds of red blood globules, viz.: first, embryonic; second, normal. The *embryonic* blood globules are double the size of the normal ones. They have a slightly granular nucleus, situated nearly in the centre, which

is insoluble in acetic acid. The *normal* blood globules are not a transformation of the embryonic. They appear by genesis in the midst of the blastema of the blood. After the fourth month, the embryonic globules cease to form, and as the mass of the blood increases, the proportionate number diminishes with great rapidity.

Leucocytes, or white blood globules, are found in many tissues, in the blood, on the surface of mucous membranes; *in a word, they are the pus corpuscles.* In form, they are round, with pale, well-defined borders, and contain extremely fine gray granules. They possess a very thin envelope, and a granular cell contents. The normal diameter is .008 millimetre ($\frac{1}{3000}$ of an inch). On the addition of water, the leucocytes swell, the granular particles are agitated by a peculiar movement (first observed by Brown), and finally, *a considerable number of these particles unite, so as to form two or three little masses, that have been mistaken for nuclei.* Upon the addition of acetic acid the same reaction follows, but with greater rapidity.

The mode of production may be followed, step by step, upon the surface of wounds, especially little ones. At first a hyaline liquid appears. At the end of a couple of hours, this liquid becomes finely granular, and then all at once, in the midst of the granulations, we perceive small granular bodies analogous to leucocytes, offering the same chemical reactions, but measuring only .003 millimetre (.000118 of an inch) in diameter. They are, in fact, leucocytes of young growth. When leucocytes are re-

tained in the economy, as in shut sacs, they increase in size, and reach a diameter of .012 millimetre ($\frac{1}{2500}$ of an inch). Then they fill with fat granules, and are known as *corpuscles of inflammation* (exudation corpuscles, compound granule cells). Finally the substance and investing membrane of the leucocytes disappear, the granules dissolve and are reabsorbed.

Capillaries.—The finest capillaries are anatomical elements of tubular form, with transparent resistant walls which measure .001 mm. (.00003937 of an inch) in diameter. These walls contain granular ovoid nuclei, which project, sometimes exteriorly, sometimes upon the inner surface of the tubes. These nuclei measure .006 mm. (.00023622 of an inch) in the transverse, and .008 mm. (.00031596 of an inch) in the long diameter. Their long axis is parallel to that of the vessel. The finest capillaries have a diameter of .007 mm. (.0003756 of an inch), leaving a calibre (after deducting the walls), of .005 mm. (.00019685 of an inch), or .002 mm. (.00007874 of an inch) less than the average diameter of the blood globules which traverse them.

They are formed as follows: 1st, In new tissues, hollow projections push out from contiguous capillaries, which meet and unite together. 2d, A solid filament forms, in which nuclei make their appearance. Subsequently, the filament becomes hollow, and its nuclei remain the nuclei of the capillary.

A single perusal of these views as thus illustrated, will convince the reader that *spontaneous formation* is the prevailing mode of origin of the elements of

tissues, according to the French school. Such perusal cannot fail to convince the reader also of the accuracy of description of the fully formed elements described by Robin.

PROF. HUXLEY,* 1869.

There is one kind of matter which is common to all living beings, and that matter is "*protoplasm*," the scientific name for "the physical basis of life." In illustration from vegetable life, each stinging needle or hair of the common nettle consists of a very delicate outer case of wood, closely applied to the inner surface of which is a layer of semi-fluid matter, full of innumerable granules of extreme minuteness. *This semifluid lining is protoplasm*, which thus constitutes a kind of bag, full of a limpid fluid, and roughly corresponding in form with the interior of the hair which it fills. When viewed with a sufficiently high magnifying power, the protoplasmic layer of the nettle hair is seen to be in a condition of unceasing activity. Local contractions of the whole thickness of its substance pass slowly and gradually from point to point, and give rise to the appearance of progressive waves, just as the bending of successive stalks of grain by a breeze produces the apparent billows of a grain-field.

But in addition to these movements, and independently of them, the granules are driven, in relatively rapid streams, through channels in the proto-

* Protoplasm; or, The Physical Basis of Life. A Lecture by Prof. Huxley, delivered in Edinburgh, Nov. 18th, 1868.

plasm which seem to have a considerable amount of persistence. The currents in adjacent parts commonly take similar directions, coursing in a general stream up one side of the hair and down the other, though partial currents also exist which take different routes; so that sometimes trains of granules may be seen coursing swiftly in opposite directions, within a twenty-thousandth of an inch of each other; and occasionally opposite streams come in direct collision, and after a longer or shorter struggle, one predominates. The cause of these currents seems to lie in contractions of the protoplasm which bounds the channels in which they flow, but which are so minute that the best microscopes show only their effects, and not themselves.

Among the lower plants, it is the rule rather than the exception, that contractility should be still more openly manifested at some periods of their existence. The protoplasm of Algæ and Fungi becomes, under many circumstances, partially or completely freed from its woody case, and exhibits movements of its whole mass, or is propelled by the contractility of one or more vibratile cilia.

In illustration of animal protoplasm, Prof. Huxley adduces the colorless corpuscles of the blood; which, under the microscope, at the temperature of the body, exhibit a marvellous activity, changing their forms with great rapidity, drawing in and thrusting out prolongations of their substance; and creeping about as if they were independent organisms. "The substance which is thus active is a mass of protoplasm, and its activity differs in detail

rather than in principle from that of the protoplasm of the nettle. Under sundry circumstances the corpuscle dies, and becomes distended into a round mass, in the midst of which is seen a smaller spherical body, which existed, but was more or less hidden, in the living corpuscle, and is called its *nucleus*. Corpuscles of essentially similar structure are to be found in the skin, in the lining of the mouth, and scattered through the whole framework of the body. Nay, more; in the earliest condition of the human organism, in that state in which it has just become distinguishable from the egg in which it arises, it is nothing but an aggregation of such corpuscles, and every organ of the body was, once, no more than such an aggregation. *Thus a nucleated mass of protoplasm turns out to be what may be termed the structural unit of the human body.* As a matter of fact, the body, in its earliest state, is a mere multiple of such units; and, in its perfect condition, it is a multiple of such units, variously modified." The formula which expresses the essential structural character of the highest animal, very nearly covers all the rest, as the statement of its powers and faculties covered that of all others. "Beast and fowl, reptile and fish, mollusk, worm, and polype, are all composed of structural units of the same character, namely, masses of protoplasm with a nucleus. There are sundry very low animals, each of which, structurally, is a mere colorless blood corpuscle, leading an independent life. But, at the very bottom of the animal scale, even this simplicity be-

comes simplified, and all the phenomena of life are manifested by a *particle of protoplasm without a nucleus.*

"What has been said of the animal world is no less true of plants. Imbedded in the protoplasm at the broad, or attached end of the nettle hair, there lies a spheroidal nucleus. Careful examination further proves that the whole substance of the nettle is made up of a repetition of such masses of nucleated protoplasm, each contained in a wooden case, which is modified in form, sometimes into a woody fibre, sometimes into a duct or spiral vessel, sometimes into a pollen grain, or an ovule. Traced back to its earliest state, the nettle arises as the man does, in a particle of nucleated protoplasm. And in the lowest plants, as in the lowest animals, a single mass of such protoplasm may constitute the whole plant, or the protoplasm may exist without a nucleus. Under these circumstances it may well be asked, how is one mass of non-nucleated protoplasm to be distinguished from another? why call one 'plant,' and the other 'animal?' The only reply is that, so far as form is concerned, plants and animals are not separable, and that, in many cases, it is a mere matter of convention whether we call a given organism an animal or a plant."

The researches of the chemist have also shown a like uniformity of chemical composition in "protoplasm" or living matter, proving that whatever its source, it contains carbon, hydrogen, oxygen, and nitrogen, producing in their combination a complex substance, which in our ignorance of its more exact nature, we call *proteinaceous* or *albuminoid matter.*

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Thus far it is plain that the views of Prof. Huxley accord with those of many eminent histologists and physiologists, the result of whose observations have been embodied in these pages, and his descriptions will be accepted as undoubtedly accurate. More widely, in common with the school of so-called "physicists," of which he is one, does he differ in his views in that which is yet to be considered, the *origin* and ultimate fate of this "protoplasm," or matter of life. According to Prof. Huxley, the matter of life is composed of ordinary matter, and again resolved into ordinary matter when its work is done. Waste is constantly going on which must be supplied by food, which is converted into protoplasm. A solution of smelling salts in water, with an infinitesimal proportion of some other saline matters, contains all the elementary bodies which enter into protoplasm, yet an animal cannot make protoplasm. And this is characteristic. It must take it ready made from some other animal or some plant, the animal's highest feat of constructive chemistry being to convert dead protoplasm into the living matter of life, which is appropriate to itself. Therefore, in seeking for the origin of protoplasm, we must eventually turn to the vegetable world. The plant, however, takes carbonic acid, water, and ammonia, and converts it to the same stage of living protoplasm with itself, though some of the fungi need higher compounds to start with; and no plant can live on the uncompounded elements of protoplasm, and the absence of any one of the elements renders the plant unable to manufacture protoplasm.

These elements, carbon, hydrogen, oxygen, and nitrogen, are related to the protoplasm of the plant as the protoplasm of the plant to the animal. *But protoplasm once produced, all the phenomena exhibited by it are simply its properties, just as the phenomena exhibited by water in its various states are properties.* They do not take place through the guidance of any principle called "vitality," any more than the phenomena of water take place by virtue of "aquosity." Prof. Huxley can discover no halting-place between the admission that protoplasm of one animal or vegetable is essentially identical with and readily converted into another, and the further concession that *all vital action* may, with equal propriety, be said to be the *result of the molecular forces of the protoplasm which displays it. The thoughts to which we give utterance are the expression of molecular changes in protoplasm.* These are admittedly so-called materialistic *terms.* Yet Prof. Huxley says: "Nevertheless, two things are certain: the one that I hold the statement (above) to be substantially correct; the other, that I, individually, am no materialist, but on the contrary believe materialism to involve grave philosophical errors." Such union of materialistic terminology with the repudiation of materialistic philosophy, he believes to be "not only consistent with, but necessitated by sound logic." This he proceeds to show in this manner: If it be supposed that knowledge is absolute, that we know more of cause and effect than a certain definite order of succession of facts, and that we have a knowledge of the necessity of that succession, then there is no

escape from utter materialism and necessarianism. But it is impossible to prove that anything whatever may not be the effect of a material and necessary cause, and no act is really spontaneous, since a really spontaneous act is one which has no cause. Yet any one familiar with the history of science will admit that its object has always meant, and means the extension of the province of matter and causation, and the concomitant gradual banishment from all regions of human thought, of what we call spirit and spontaneity,—that is, the object of all science has been and is to find out the causes of all phenomena; and there is no difference between the conception of life as the product of a certain disposition of material molecules and the old notion of an Archæus governing and directing blind matter within each living body, except that here, as elsewhere, matter and law have devoured spirit and spontaneity. And moreover, the physiology of the future will gradually so extend the realm of matter and law, until it is coextensive with knowledge, with feeling, and with action. It is this *progress of knowledge*, according to Prof. Huxley, which so many of the best minds conceive to be the *progress of materialism*, which they watch with such fear and powerless anger as a savage feels, when, during an eclipse, the great shadow creeps over the face of the sun. We know nothing of this terrible "matter," except as the name for the unknown and hypothetical cause of states of our own consciousness, and as little of that "spirit," except that it is also a name for an unknown and hypothetical cause of states of conscious-

ness, that is, matter and spirit are both names for the imaginary substrata of groups of natural phenomena. Dire necessity and "iron" law are gratuitously invented bugbears. If there be an "iron" law, it is that of gravitation, and if there be a physical necessity it is that a stone unsupported will fall to the ground. We know nothing more of this latter phenomenon, except that stones always have fallen to the ground under these conditions, and that they will continue to fall to the ground thus unsupported.

It is simply convenient to indicate that all the conditions of belief in this case have been fulfilled, by calling the statement that unsupported stones will fall to the earth a "law of nature." But when for *will* we exchange *must*, we introduce an idea of necessity which does not lie in the observed facts, and is not warranted by anything that is discovered elsewhere. And with regard to which Prof. Huxley says: "For my part, I utterly repudiate and anathematize the intruder. Fact I know, and Law I know; but what is this Necessity, save an empty shadow of my own mind's throwing? But, if it is certain that we can have no knowledge of the nature of either matter or spirit, and that the notion of necessity is something illegitimately thrust into the perfectly legitimate conception of law, *the materialistic position that there is nothing in the world but matter, force, and necessity, is as utterly devoid of justification as the most baseless of theological dogmas.*

"The fundamental doctrines of materialism, like those of spiritualism, and most other 'isms,' lie outside 'the limits of philosophical inquiry,' and David

Hume's great service to humanity is his irrefragable demonstration of what these limits are. Hume called himself a skeptic, and therefore others cannot be blamed if they apply the same title to him; but that does not alter the fact that the name, with its existing implications, does him gross injustice. If a man asks me what the politics of the inhabitants of the moon are, and I reply that I do not know; that neither I, nor any one else have any means of knowing; and that, under these circumstances I decline to trouble myself about the subject at all, I do not think he has any right to call me a skeptic. On the contrary, in replying thus, I conceive that I am simply honest and truthful, and show a proper regard for the economy of time. So Hume's strong and subtle intellect takes up a great many problems about which we are naturally curious, and shows us that they are essentially questions of lunar politics, in their essence incapable of being answered, and therefore not worth the attention of men who have work to do in the world." . . . .

"If we find that the ascertainment of the order of nature is facilitated by using one terminology, or one set of symbols, rather than another, it is our clear duty to use the former, and no harm can accrue so long as we bear in mind that we are dealing merely with terms and symbols. In itself it is of little moment whether we express the phenomena of matter in terms of spirit, or the phenomena of spirit in terms of matter; matter may be regarded as a form of thought, thought may be regarded as a property of matter—each statement has a certain relative

truth. But with a view to the progress of science, the materialistic terminology is in every way to be preferred. For it connects thought with the other phenomena of the universe, and suggests inquiry into the nature of those physical conditions, or concomitants of thought, which are more or less accessible to us, and a knowledge of which may, in future, help us to exercise the same kind of control over the world of thought as we already possess in respect to the material world; whereas, the alternative, or spiritualistic terminology is utterly barren, and leads to nothing but obscurity and confusion of ideas. Thus, there can be little doubt that the further science advances, the more extensively and consistently will all the phenomena of nature be represented by materialistic formulæ and symbols. But the man of science, who, forgetting the limits of philosophical inquiry, slides from these formulæ and symbols into what is commonly understood by materialism, seems to me to place himself on a level with the mathematician, who should mistake the *x's* and *y's*, with which he works his problems, for real entities—and with this further disadvantage, as compared with the mathematician, that the blunders of the latter are of no practical consequence, while the errors of systematic materialism may paralyze the energies and destroy the beauty of a life."

These are the views of the "physicists," so-called, a school represented by Prof. Huxley, Prof. Owen, Herbert Spencer, Mr. Grove, Prof. Tyndall, and others. Prof. Owen, in the last pages of vol. iii of "The Anatomy of the Vertebrates," declares him-

self the champion of spontaneous generation, and he maintains, also, that the formation of living beings out of *inanimate matter* by the conversion of physical and chemical into vital modes of force, is a matter of daily and hourly occurrence. Mr. Grove says that "in a voltaic battery and its effects we have the nearest approach man has made to an experimental organism," and that in the human body we have chemical action, electricity, magnetism, heat, light, motion, and possibly other forces "contributing, in the most complex manner, to sustain that result of combined action we call life."

We trust it is not necessary to state that it has been attempted to state these views, not in a spirit of criticism, but fairly and justly; our object in this connection being simply to exhibit the present state of the subject as viewed from all standpoints. And in the case of this class of eminent observers we have based our account almost entirely on what we believe the latest exposition of the subject, viz., Prof. Huxley's lecture, while we have included, also, such quotations of pregnant sentences of other observers of the same class, as seemed essential to completeness and consistent with brevity.

THE AUTHOR'S VIEWS.

As the result of a careful comparison of the views of other observers, and of personal observation, extending over a period of several years, chiefly in the direction of human physiology and pathology, the author has been led to adopt views, which, in the main, correspond with those of Dr. Beale. There

are, however, a few points of difference; some, perhaps, purely in mode of expression, but others as to matter of fact, which would seem to be appropriately here recorded. And, in order to give completeness to any expression of such views, he has thought best to state them connectedly, though briefly.

The author believes the ultimate physical element of organization, to be what is commonly called the "cell," or "elementary part," and that it is composed of matter in two states. The one, central in its situation, to which Dr. Beale has most appropriately given the name "germinal matter;" the other, for the most part peripheral in its situation, which the same observer has called "formed matter." The former, which is the "sarcode" of Dujardin, the "protoplasm" of Max Schultze, is that upon which the *origin* and *existence* of the cell depends. It is derived by division, budding or proliferation from previously existing matter of the same kind, and it alone has the power of growing by converting nutritious matter or "pabulum," derived from the blood or other sources, into material like itself. Without germinal matter textures cannot be reproduced or continued.

In appearance, germinal matter is *often* structureless, especially as constituting the living moving matter of the protozoa or lowest animals of the rhizopod type, as the amœba. Yet it is not always structureless, but often *granular* in its appearance, and as constituting the mass of rapidly growing cells in health and disease, in the higher animals, is indeed *usually* granular, as is evident from the

study of pus, or mucous, or white blood corpuscles, or the cells of a rapidly growing morbid growth. Indeed it seems like sacrificing observation to theory, to say that germinal matter is always structureless. For let us take the white blood corpuscle or pus corpuscle, acknowledged to be pure germinal matter, and always described as granular in its structure; either the germinal matter here is granular, or the granules are particles of formed material or extraneous matter suspended in the formless substance, just as granular matter from without becomes entangled in the formless matter of the amœba. But, such a view as the latter, would be incompatible both with the behavior of growing germinal matter, and the reaction by which it is known; for we note, on the one hand, that when germinal matter grows rapidly, these granules are the elements which increase most abundantly; and again, that these are the portions most deeply stained by ammoniacal solutions of carmine or aqueous solutions of red aniline. Especially must this be the case if the so-called nuclei of these bodies, which appear after the addition of water and acetic acid, are simple aggregations of the granular matter, as is contended by Dr. Beale. We deem it incorrect, therefore, to describe germinal matter as in all instances structureless, and prefer, with Robin, to describe it as sometimes granular. Indeed, if we mistake not, Dr. Beale in his earlier descriptions also characterized it as granular.*

* Beale's Archives of Medicine, vol. ii, p. 189.

A circumscribed round or oval portion of germinal matter within the cell is usually termed the *nucleus*, which may be surrounded by formed material as in the superficial epithelial cell, or by other germinal matter as in the white blood corpuscle.

In the *nutrition* of the cell, the pabulum comes to it from the periphery; being strained through the formed material, and the new germinal matter takes its place in or near the centre of the original mass, constituting a new centre of germinal matter, which may be the nucleus, if no other circumscribed centre be present, or the *nucleolus* if it be deposited within such a centre. Other new centres may again take position within these, and assume the relation of nucleolus to the original nucleolus, which now becomes the nucleus, an older centre of germinal matter; while the original nucleus has probably been converted into the second constituent of the cell, the formed material.

Germinal matter when free and living, exhibits a power of movement, both in *portions* of its substance, producing changes in shape, and in its *entire mass*, resulting in changes of position. The former, and probably, also, the latter, may have for their object the obtaining of pabulum, as is seen in the amœba, when it embraces by its protrusions, a particle of nutritive matter. These movements are less decided in the cells of the higher animals, yet they are of constant occurrence, as in pus and white corpuscles, and when thus occurring they are spoken of as "amœboid movements." Allied or identical with this second class of movements, are those of undoubted occur-

rence, in which white blood corpuscles have been noted by Addison,* Waller,† and Cohnheim,‡ migrating from the bloodvessels, and constituting *one* method of origin of pŭs.

Formed Material, or Non-Germinal Matter.—As the result of influences, the exact nature of which is not known, though some of them may partake of the character of oxidations, the germinal matter is converted into the second constituent of the cell, *formed material.* This formed material, peripheral, for the most part in its situation, and constituting the cell wall, when present, is without the property of germinating, or multiplying itself, or even maintaining itself. Yet it is exceedingly important, and as essential indeed to the functions of the economy, as the germinal matter. It is, in fact, the portion of the cell in which alone function resides, since it is to the formed material of the muscle-cell that we owe the property of contractility, to the formed material of the nervous element that we are indebted for neurility, and to the formed matter of the epithelial cell that we owe its protective qualities; while the secretion of all glands, whether they subserve ulterior purposes or not, is the formed material of the respective gland-cells. Hence, we would not in every instance speak of the formed material as dead, where it is the seat of so many important vital endowments,

* Addison, Physiological Researches. London: 1841.

† Waller, London, Dublin and Edinburgh Philosophical Magazine, vol. xxix, p. 271, 1846.

‡ Cohnheim, Ueber Entzündung und Eiterung, Virch. Arch. Bd. xl, p. 48.

as in muscle and nerve. In some situations, it is indeed lifeless, as when it becomes the secretion of glands, as bile and milk, or the peripheral part of epithelial cells. It simply is devoid of a power of multiplying or growing by itself, depending for its increase upon the conversion of the germinal matter. Hence we have been inclined to suggest the term "non-germinal," or "non-germinating" matter, since this is the only attribute common to all formed material.

In *structure*, formed material or non-germinal matter is varied. Thus, it is typically without structure in the red blood disc; again it exhibits distinctive structure in the striped sarcous matter of muscle, and in the fibrous intercellular substance of white fibrous tissue or fibro-cartilage.

As formed material is produced on the periphery of germinal matter, previously existing formed material is pushed outward, so that the oldest formed material is that most remote from the germinal matter, and the youngest lies immediately adjacent to it.

Intercellular substance, whether of cartilage or white fibrous tissue, is formed material, resulting from the conversion of the germinal matter, which constitutes the cartilage corpuscle on the one hand, or the connective tissue corpuscle on the other. It is not of the nature of a deposit from the bloodvessels which subsequently becomes differentiated. Young cartilage cells, like all young cells, consist of almost pure germinal matter, and the capsule of the cartilage corpuscle is but formed material, more or less continuous and inseparable from the intercellular sub-

stance; so that we would, with Beale, define a cartilage cell, or elementary part of cartilage as composed of germinal matter, with as much surrounding formed material as extends half way to the adjacent germinal matter. So with the elementary part of connective tissue, muscle, and nerve.

Oil and starch are also formed matter, conveniently designated by Dr. Beale as *secondary* formed matter, and result, also, from a conversion of the germinal matter.

As already stated, the proportion in which these two constituents are present, is various. Thus, in the amœba, in the white blood disc, in the pus and mucous corpuscle, we have almost pure germinal matter, with a scarcely appreciable ring of formed matter on its periphery; while in the old epithelial cell we have almost pure formed material with a mere point of germinal matter, constituting the nucleus near its centre; and in the red blood disc, we have pure structureless formed matter, yet matter of which we should long hesitate to speak as dead. In old tendon, again, the proportion of formed material is large, and germinal matter small, while in young tendon the reverse proportion exists.

The *cell*, as thus constituted, and originating only in the germinal matter of a previously existing cell, we believe to be *the starting-point of all life action, be it healthy or morbid.* Out of this cell, all tissues, simple and complex, are constructed.

We believe, also, that the proper shaping, arrangement, and function of these elementary parts is not a process identical or analogous to crystallization, tak-

ing place through merely physical laws, but that there is a presiding agency which controls such arrangement to a definite end. It matters not what this is called, but we prefer to designate it at present by the term "vital force," or "vitality." It is this controlling agency which makes all so-called vital properties essentially different from purely physical properties, a difference which, though it be denied in *words*, and explained away by reasoning, has the most decided proof of its existence in the acknowledgment it receives in the *actions* of men, just as the most convincing argument in favor of the free agency of the human mind is seen in the fact, that all men shape their actions on the supposition of such a freedom, whatever their pretended belief with regard to it.

That there is something in this force or power over and above the physical forces of nature, is most strikingly shown in the power, exhibited through its agency by germinal matter, of multiplying and producing new germinal matter out of pabulum unlike itself. For although a crystal may result from the rearrangement of particles of a salt in solution, as sulphate of alumina, to an unlimited extent, there is no possibility, nor would any physicist contend that it could produce crystals, of its own composition, out of carbonate of soda. Nor, as is justly contended by Dr. Beale, should the cell be compared to a machine, unless that machine possess a power of producing new machines out of material unlike itself, and of endowing them with a similar power.

In *morbid processes*, also, the germinal matter is the seat of activity, being abnormally increased, dimin-

ished, or perverted; and many pathological states are rationally explained by bearing in mind the properties of germinal matter and the very minute size which the living particles may exhibit. All physical difficulties in the way of the passage of white blood corpuscles through the walls of capillaries are removed, when we remember that the smallest living particles by the rapid growth of which white blood discs or pus corpuscles are speedily produced, do not exceed the $\frac{1}{100000}$ of an inch in diameter, and that however unreasonable it may appear for a body $\frac{1}{3000}$ of an inch in diameter to migrate through continuous capillary walls, it becomes much less unreasonable when we thus reduce its proportions. The observations of Beale would also seem to reconcile the discordant views with regard to the so-called *exudations*, in which on the one hand we need not suppose an excessive dislocation of structure to admit the passage of large cells, and on the other are not compelled to restrict the origin of those cells to points outside the vessels. We have already expressed that the views of H. Charlton Bastian and Cornil, with regard to the origin of tubercle in the perivascular sheaths of vessels, are not practically different from those earlier expressed by Beale as to its origin in the germinal matter of the walls of bloodvessels.

It will be noted that the only points of difference between our own and the views of Dr. Beale, lie in the structure of the germinal matter, and the use of the word *living* to characterize formed material. In all other respects, we accept the theory of Beale, and have no hesitation in saying that it admits, with-

out distortion of its own principle or disregard of actual facts, of consistent application to a larger number of processes of tissue-building in health and disease, than any other theory proposed.

In conclusion, then, it may be stated, 1st, that the "cell," or "elementary part," originating only in a pre-existing cell, is the ultimate morphological element of the tissue of animals and plants.

2d. That the cell, contrary to the belief of the earlier histologists, and, indeed, many later observers, is *rarely vesicular* in its structure, but generally more or less solid throughout.

3d. That the cell is composed of "germinal" or living matter which is central, and includes "nucleus," "endoplast," "protoplasm" and "sarcode;" and of "non-germinal," or "formed" matter, which is peripheral, and corresponds with "cell wall" and "intercellular substance."

4th. That this germinal matter of the cell in a part or all of its substance, may assume a special morphological state, usually round or oval, commonly known as the "nucleus" of the cell, which, when present, is always a young centre of germinal matter; but that in other instances both animal and vegetable cells may be complete without this special form of germinal matter or "nucleus," as in the non-nucleated amœbæ and protogenes primordialis of Hæckel, the non-nucleated monads of Cienkowsky, and in the leaf of Sphagnum, in such Algæ as Hydrodictyon, Vaucheria, and Caulerpa, and in young germinating ferns.

5th. That in consequence of these facts, it cannot

be said that in the nucleus alone resides the power to reproduce the cell, since we find the nucleus not essential, but that in the germinal matter, of which after all, the nucleus, when present, is but a part, resides this function.

6th. That when the smaller body within the nucleus, usually known as the "nucleolus," is present, as it often is in complete cells, it is simply a younger centre of germinal matter than is the nucleus itself, and is the last formed portion of germinal matter, instead of being the oldest part of the cell, as originally taught by Schleiden and Schwann. And thus, according to the latest views, the whole process is reversed. The old order of succession being, 1st. The "nucleolus;" 2d. About this the "nucleus;" and finally about this the "cell wall," which embraces the cell contents. Now, however, what constitutes the "cell wall" when present, is the oldest part of the cell; next in age are the so-called "cell contents," whether germinal matter or not; next the "nucleus," and last and youngest the "nucleolus."

7th. That the formed material constituting the cell wall and intercellular substance may be something chemically different from the germinal matter, or protoplasm whence it was converted, as the secretions of gland-cells, or may be a simple condensation of the exterior of the cell, as in the red blood disc.

8th. That the so-called "free nuclei," so often referred to by pathologists in their descriptions of minute structures, are simply masses of germinal matter, smaller than those to which the name cell is usually given, which, if time be permitted, will pass into

perfect cells by the usual production of formed matter on their periphery; that they do not originate spontaneously, but from previously existing germinal matter. So, too, "granules," if they be composed of germinal matter, present the same attributes and endowments, arising from previously existing germinal matter, capable of growing, multiplying, and assuming all the characters of fully formed cells, but never originating spontaneously. Granules otherwise composed are *histolytic* (ιστος, a tissue, λυσις, a breaking), and *not histogenetic* (ιστος, a tissue, γενεσις, creation),—that is, they result from the breaking down of tissue rather than go to building it up.

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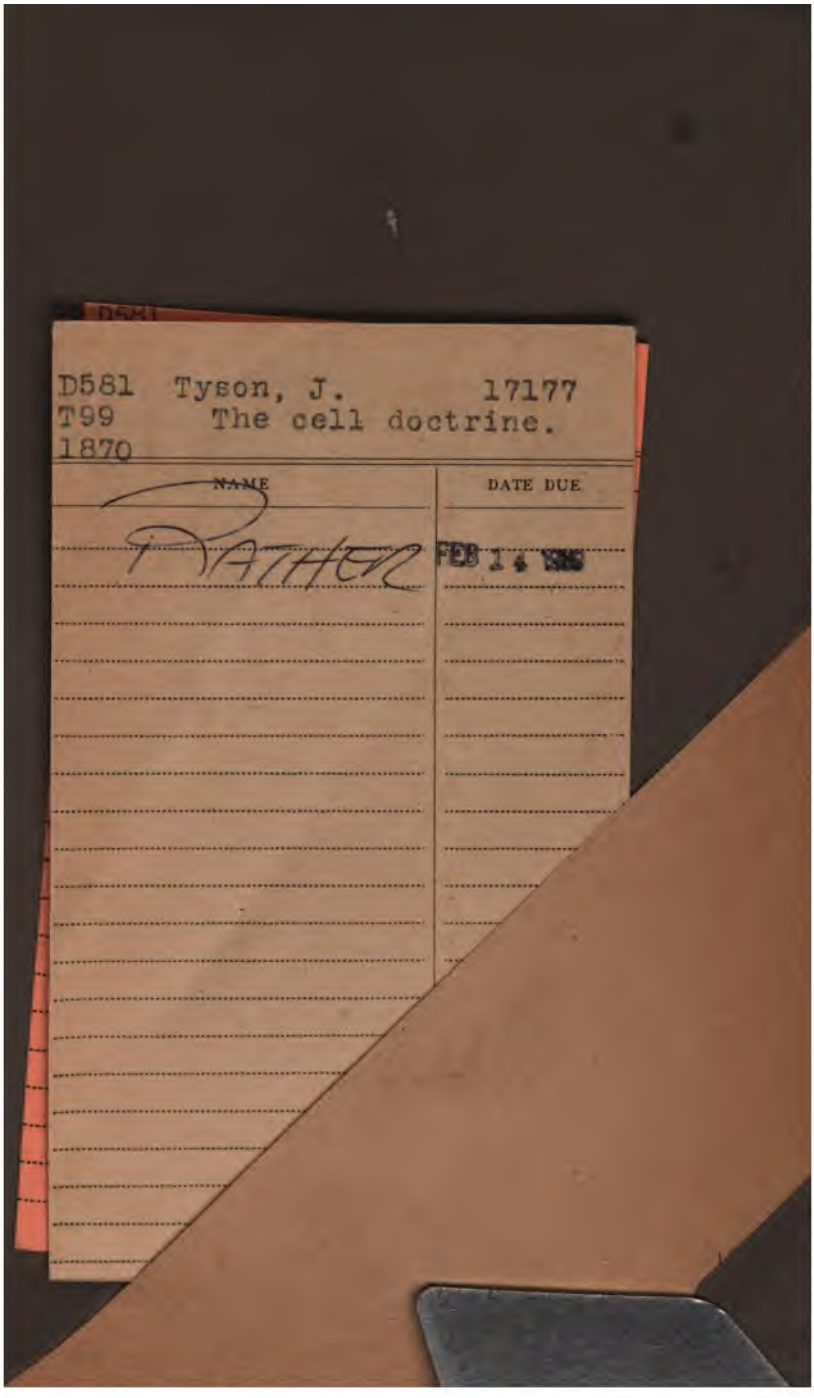
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